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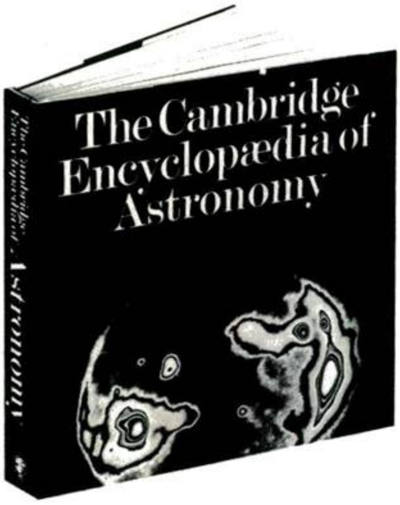
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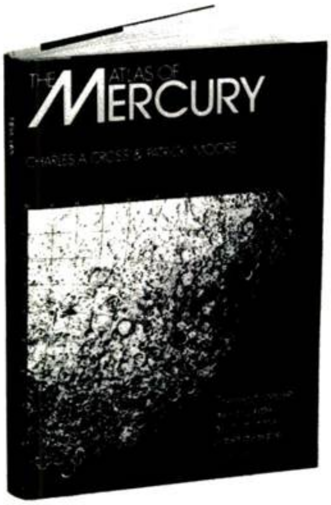
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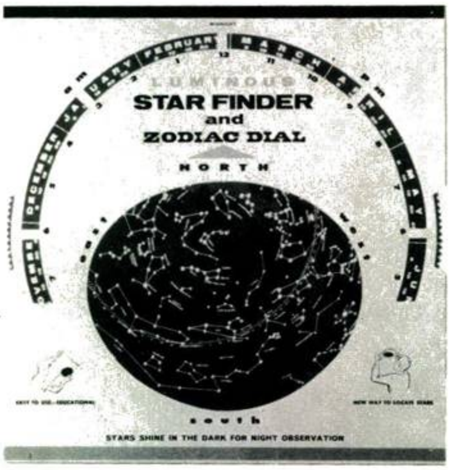
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Cover

Earth is a special planet to mankind — more than just a home, our place of origin. But how did Earth itself come into being and how did it change and become the planet we now know? This month ASTRONOMY explores the origin of Earth, what it's like today, and the origin of the ocean basins that distinguish our planet from all others. On our cover you see Cape Canaveral and the launch pads of Kennedy Space Center far below the booster in the foreground, dramatizing our escape into space — and our new vision of our planet. NASA Apollo 7 photograph.

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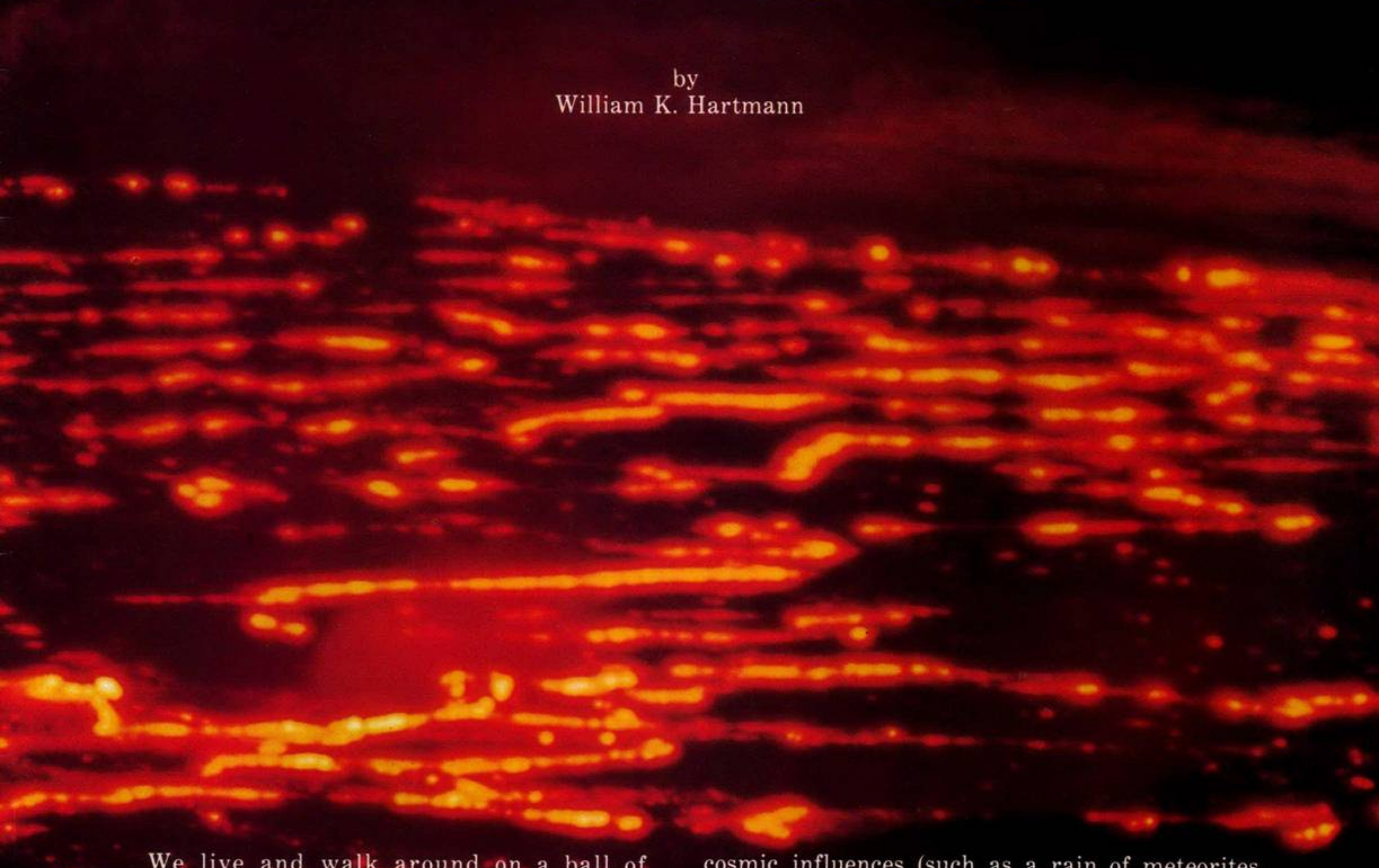
Early in Earth's history, volcanos sprewed molten rock and gases to the surface, adding water, carbon dioxide and other gases to the primitive atmosphere. The process still continues today even though volcanos are not everyday experiences for most of us. As lava flows in Halamaumau Crater, Hawaii, incandescent lava shines through when the cooler surface crust cracks. Photograph by Dale Cruikshank and William Hartmann.

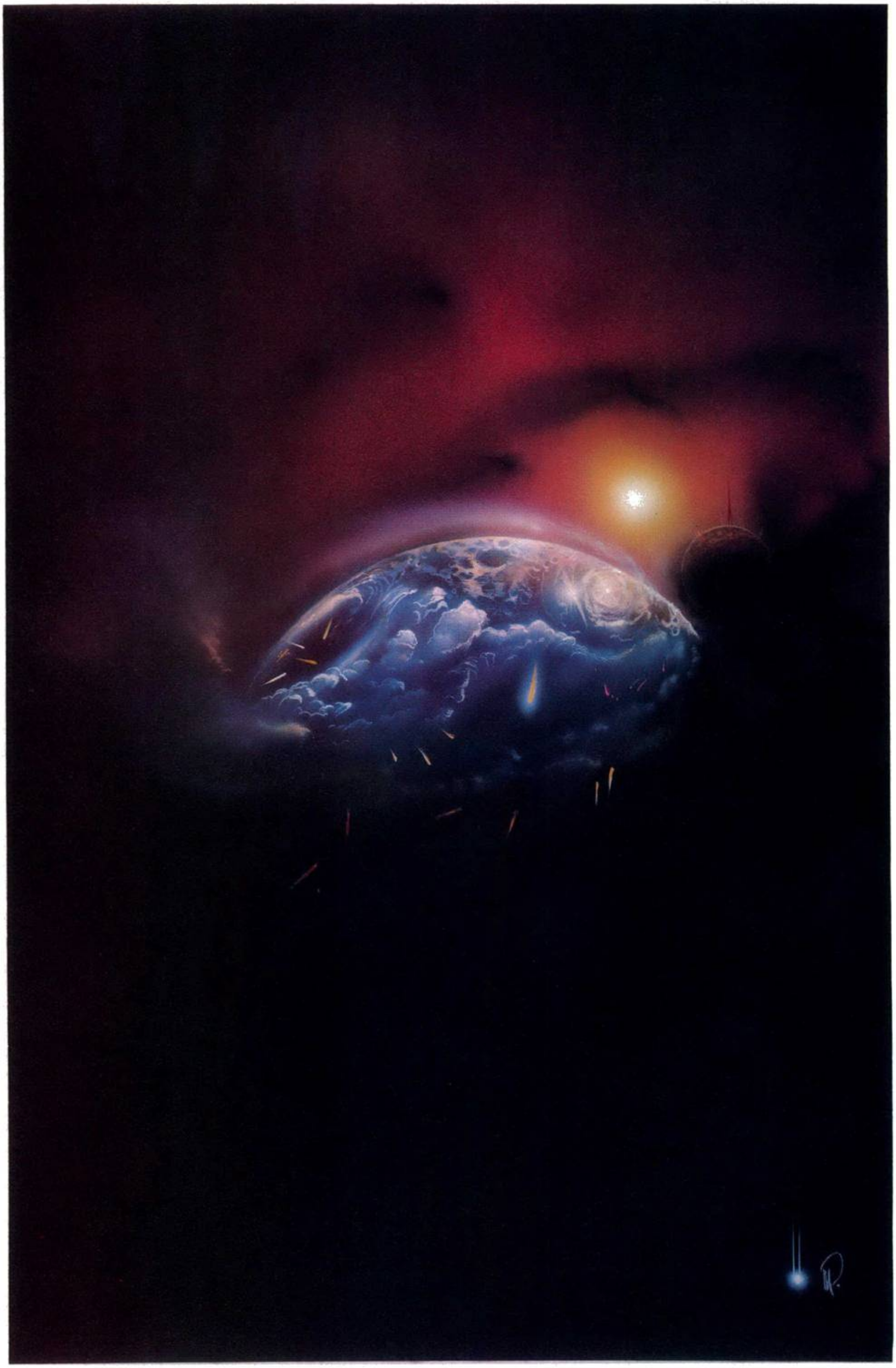
The Early History of Planet Earth

by
William K. Hartmann



We live and walk around on a ball of magnesium silicates and iron that formed in a cloud of dust and gas some 4-1/2 billion years ago. In short, Earth is the closest planet and most accessible astronomical object. The rocks beneath our feet may shed light on less easily reached places that exist elsewhere in the solar system — or on Earth sized masses near other stars.

The early history of Earth is of special interest; it marks a period of transition from a time when the main processes affecting Earth were external (or astronomical) to a time when they were internal (or geological). Earth's formation was, by definition, entirely astronomical — particles orbiting a central star aggregated into a planet. Later, external cosmic influences (such as a rain of meteorites, nearby supernovae, and strong solar winds) continued to dominate, but internal processes (such as heat production by radioactivity in the rocks) probably contributed to a melting of the internal layers. The first quarter or so of Earth's history — let's say the first billion years, from 4.6 to 3.6 billion years ago — saw the main transition from an alien, cosmically influenced terrain to a more familiar terrestrial environment. At present, the supply of cosmic meteorite debris has been largely swept up, nearby supernovae are rare, and the sun has settled down to relative stability. Internal geological processes such as circulation of interior molten rock and erosion of the surface by water now dominate



the formation of structures that we see around us.

Five important processes shaped the early Earth: 1) the growth of Earth to its present mass; 2) the heating, melting and chemical differentiation to give present rock types; 3) changes in Earth's rotation probably related to the origin of our moon; 4) evolution of the crustal rocks and surface structures, and 5) evolution of oceans and the atmosphere, whose nature is even more remarkable when contrasted with the atmospheres of our neighboring planets, Venus and Mars. For each process there is a consensus — a "best buy" theory — and a number of alternate ideas competing for more general acceptance. We will emphasize the consensus, but touch upon competing ideas. There are still so many unanswered questions that planetary scientists, astronomers, geologists and chemists still have decades of work before them.

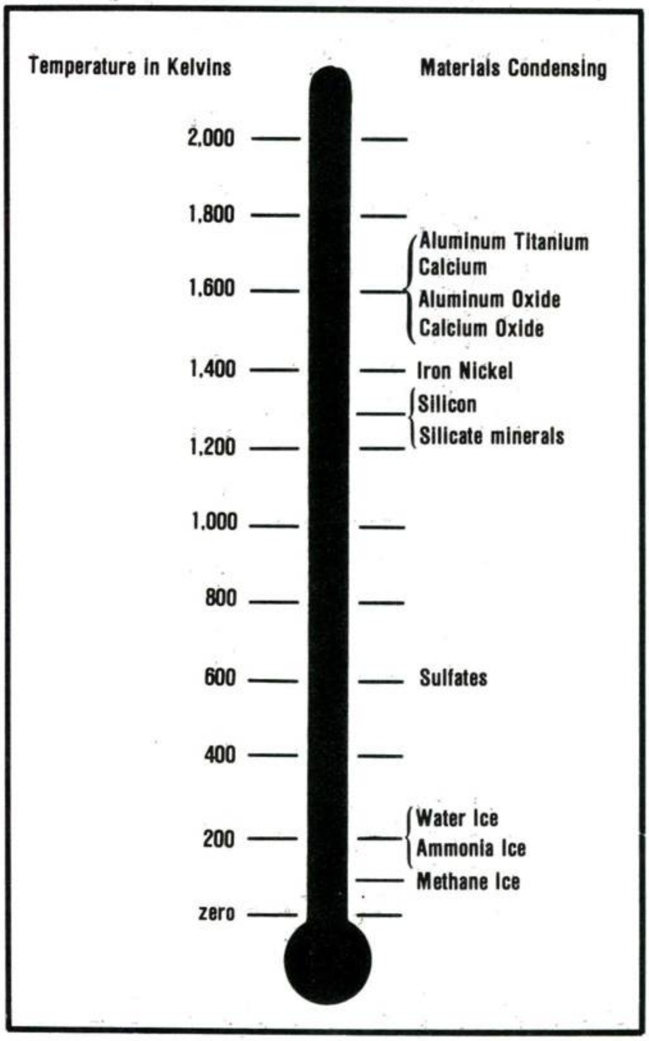
The Growth of Earth

The growth of Earth almost certainly occurred in a cooling nebula around the newborn sun. Astronomers currently observe such nebulae around other newly forming stars. The gas consists of the basic mixture found in spiral galaxies — mostly hydrogen and helium with a small percent of heavier elements such as iron, silicon and oxygen. As any gas cools, some substances in the gas may crystallize into drops or grains when appropriate temperatures are reached. Raindrops, snowflakes and hailstones condense out of moist cooling air, for example.

By the time the cooling gas around the early sun reached temperatures around 1,400 degrees Kelvin, chemical calculations show minerals such as iron oxides, titanium oxides and nickel-iron had condensed to form microscopic *mineral grains*. By 1,300 degrees Kelvin, still more abundant silicate rock forming minerals were condensing out in the form of *dust grains*. When temperatures dropped as low as 100 to 300 degrees Kelvin, ice crystals of water, ammonia and methane condensed. This chemical theory —which pictures an early time when microscopic stony and icy grains orbited in a dusty nebula around the sun — has recently been confirmed by actual astronomical observations. In dusty nebulae surrounding distant, newly forming T-Tauri stars, astronomers find the spectra of silicate and ice particles. Further confirmation comes from the structure of primitive meteorites — those that never heated enough to cause complete melting. They show a matrix of microscopic, aggregated grains of silicates, iron minerals and traces of water.

Somehow these solid materials aggregated into planets with the compositions we see today. Suppose that the circumsolar gas — the source of the condensable material — was swept away by outrushing solar wind as the new sun began to burn, leaving the grains behind. This simple idea explains much planetary chemistry. The hotter regions inward of Earth's orbit would be richest in the iron-rich high temperature minerals, allowing a very iron-rich planet such as Mercury to form. Earth's zone would have a higher proportion of the lower temperature silicate minerals, explaining its greater proportion of rocky material. Farther from the sun, Mars would have a still smaller proportion of iron, explaining its lower density (than Earth's). Still farther outward among the Jovian planets, where temperatures were still lower, hydrogen-rich ices (water, ammonia and methane) dominated the planet forming material, explaining the hydrogen-rich giant planets. Most researchers agree that this basic chemistry was the main factor controlling the composition of Earth.

Earth grew through accretion of material from the solar nebula. Particles, in every size ranging from dust to major asteroidal bodies, added mass to the growing object that would eventually become Earth. Though long by human standards, Earth reached nearly full size in an astronomically short time — probably around 50 million years. Artwork by Mark Paternostro.



As the solar nebula cooled, constituents of the original gas cloud condensed to form tiny grains and crystals. Though the order of condensation is the same everywhere, parts of the solar nebula closest to the sun may well have been hotter — and hence contained metal oxides and silicates sooner — than the outer parts of the solar system.

The details of theories on the aggregation process differ. Some analyses of the nebula surrounding the early sun suggest that the dust in

Earth's vicinity could have condensed out of the gas and aggregated in a single step into spheres due to the gravitational attraction of the grains for each other. Some calculations suggest these *planetesimals*, the size of asteroids, were only a few miles across. Other calculations conclude that gravity would have dragged in both gas and dust to form massive *protoplanets*, the size of Earth, in a single step. This type of formative process is called *gravitational collapse*.

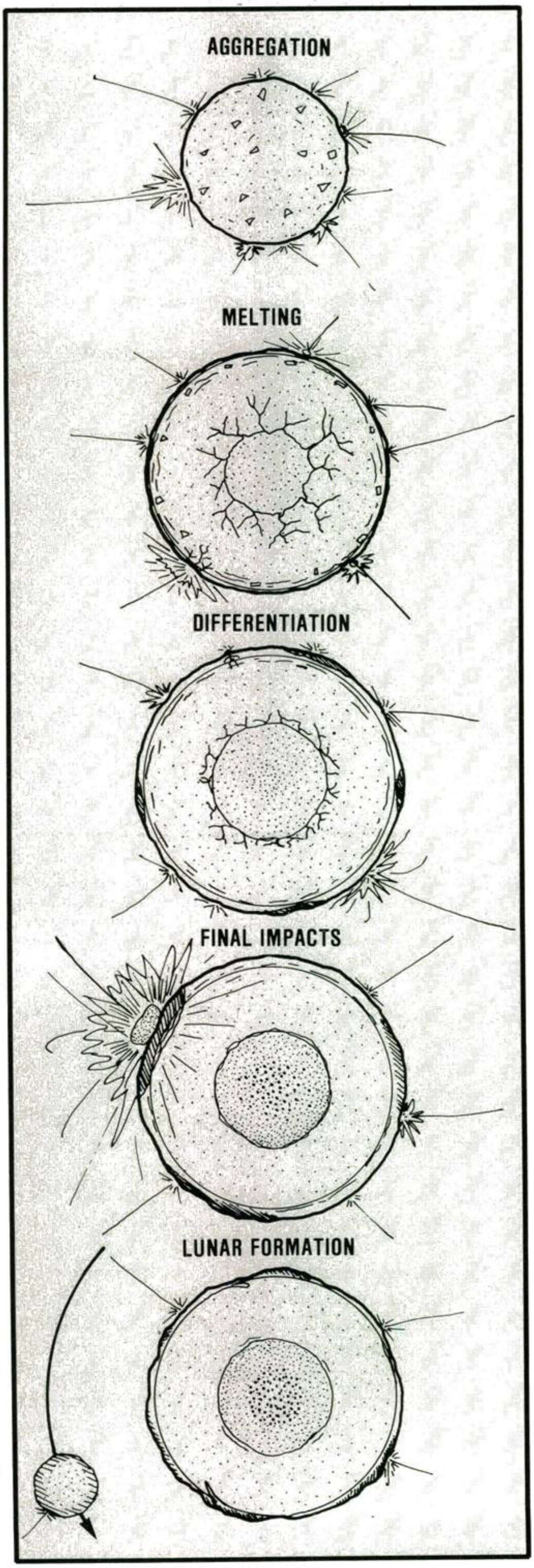
Other theories assert that a long series of collisions of one planetesimal with another — and not gravitational collapse — was required to build Earth up, stepwise, to its current mass. It's likely that condensation of grains, collapse of grains into small planetesimals, and aggregation of planetesimals by accretion all occurred during the formation of Earth. Again, evidence favoring this complex process comes from meteorites that show definite evidence of original grain condensation, followed by many generations of collision in which planetesimals grew, were fractured, and had their fragments later incorporated inside other growing bodies.

Whatever the details, the Earth-growing process was (astronomically) short. Meteorite studies show that *their* aggregation occurred probably within a few million years, and studies of lunar and terrestrial rocks indicate that the Earth-moon system probably formed in less than 90 million years. We can say that Earth probably had reached its present size by 50 million years ago, and almost certainly within 90 million years.

These studies are further confirmed by a different type of analysis of isotopes formed by radioactive atoms in the oldest terrestrial rocks. In a 1977 report, Caltech scientists A. J. Gancarz and G. J. Wasserburg presented radioisotope age results from 3.59 billion-year-old rocks from West Greenland. The rocks' properties suggest that Earth itself formed in the interval from 4.47 to 4.55 billion years ago, depending on the amount of metamorphism (or geological disturbance) of the Greenland rock samples.

Heating, Melting, Differentiation

How did Earth get its core of metallic nickel-iron, its mantle of dense rock, and its crust of lower density rock? Formation of these layers was certainly part of the early history of the planet, but when and how did it happen? The simplest theory relates the structure to the sequence of condensation in the early cooling nebula. The nickel-iron minerals which condensed first might have completely aggregated first into a large sphere —Earth's core. Then, as the temperature



Throughout its early history, Earth was under continuous bombardment by objects formed in the early solar system. During the aggregation phase, Earth was built up from millions of bodies of all sizes. As the rocky mass melted and differentiated, material continued to fall in. One or more of the final impacts may have been truly giant ones — contributing to the weakness of the planetary crust and ejecting enough material to form the moon.

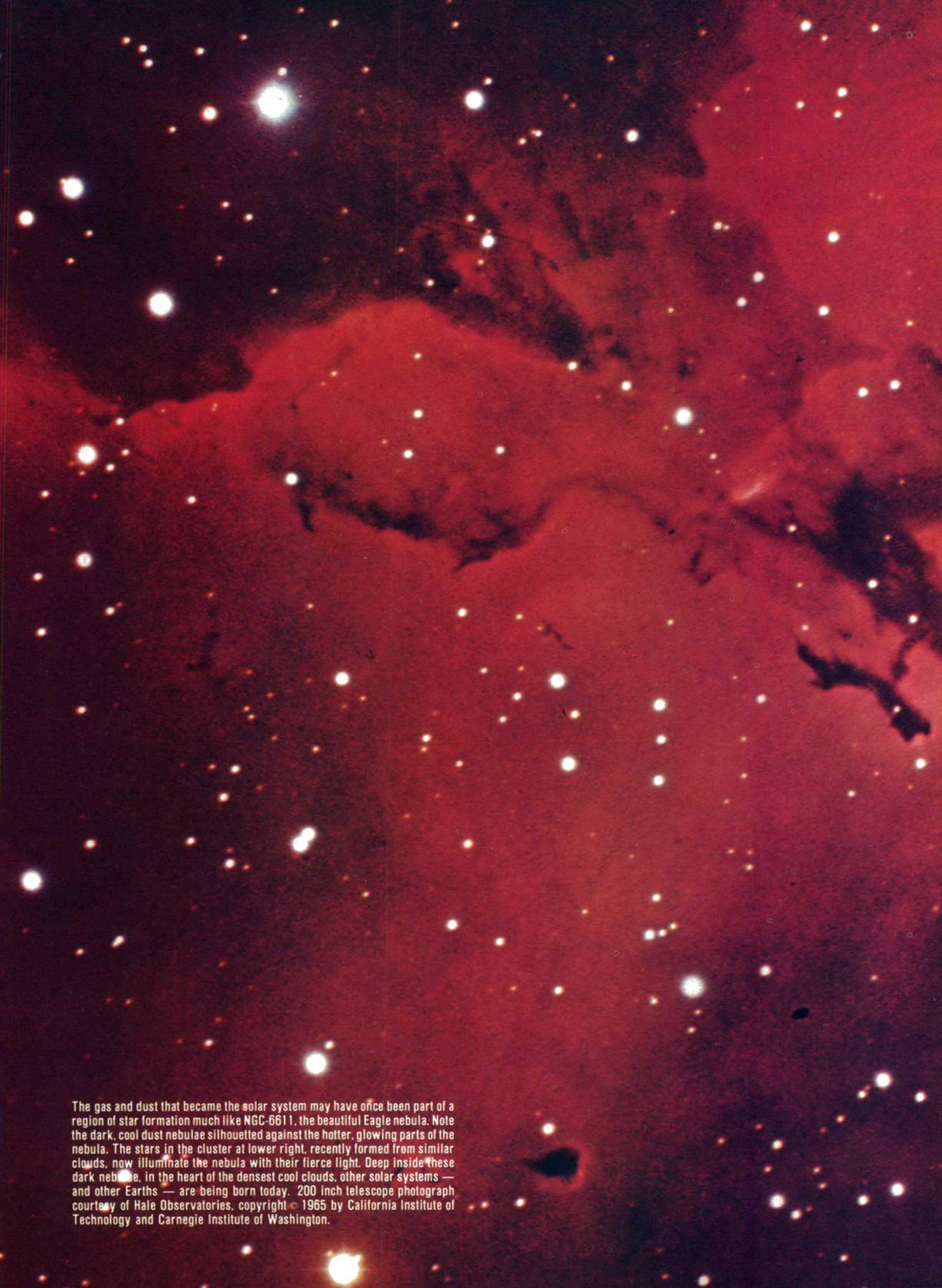
These sterile volcanic rocks and pumice may resemble Earth's surface before life appeared. Though desolate during the billions of years before living creatures transformed the planet, Earth was not static. Eroded by wind and rains, the planet's surface was certainly an active and changing place. This green basalt lava field lies near the summit of Mauna Loa, the giant volcanic shield in Hawaii. Photograph by William Hartmann.

dropped, silicate minerals might have formed and coated the nickel-iron planet to form Earth's mantle. Most theorists, however, believe the nickel-iron grains didn't have time to form a large body before the silicate minerals condensed and mixed intimately with them. According to the consensus, then, Earth formed as an essentially homogeneous body, made up of finely mixed iron and silicate materials resembling meteorites or iron-rich volcanic rocks.

How, then, did the core form? If you were to melt such rocks, as in a smelter, the dense iron droplets would sink through the molten silicate mush to the bottom, while iron-poor silicate material, resembling granite rocks, would float to the surface. Such layering is very similar to that in Earth, so most theorists believe Earth's structure may have come about by melting of the interior. Though the moon lacked enough iron to form a sizable metal core, lunar rocks indicate that it underwent similar melting, with the lowest density rocks concentrated near the lunar surface.

If layering occurred because of melting, the question now becomes: *How did the planets get hot enough to melt?* Theorists have suggested a number of heat sources, such as the early explosive bombardment of the surface by meteorites, or heating by electric currents generated as the sun's magnetic field swept past Earth in the solar wind. But among planetary scientists, the consensus is that most of the heat came from the radioactive elements incorporated in Earth along with the other rock forming elements. Heat is just another name for atomic motion. When radioactive atoms disintegrate, they shoot subatomic particles into surrounding atoms and increase their motions. We know by direct measure that *long-lived* radioactive atoms such as uranium, thorium and potassium-40 were incorporated in Earth, the moon and meteorites. Growing evidence suggests that a supernova in a nearby star, shortly before or during formation of our solar system, contaminated planetary material with additional *short-lived* radioactive atoms. These atoms provided more heat in the early days than is released now. Since that time, all the short-lived isotopes have disintegrated.

Researchers in various countries have computed how long it would take the various kinds of radioactive atoms to melt an initially homogeneous Earth. Two Russian scientists have assumed an initially uniform Earth, and then allowed heat (mainly from uranium, thorium and



The gas and dust that became the solar system may have once been part of a region of star formation much like NGC-6611, the beautiful Eagle nebula. Note the dark, cool dust nebulae silhouetted against the hotter, glowing parts of the nebula. The stars in the cluster at lower right, recently formed from similar clouds, now illuminate the nebula with their fierce light. Deep inside these dark nebulae, in the heart of the densest cool clouds, other solar systems — and other Earths — are being born today. 200 inch telescope photograph courtesy of Hale Observatories, copyright © 1965 by California Institute of Technology and Carnegie Institute of Washington.

potassium-40) to melt the planet. They accounted for complications such as energy from the sinking iron and the viscosity of the melting material. They concluded that iron would have been draining from the outer portions toward the center when the rocks reached near-molten temperatures 500km (approximately 311 miles) below the surface about 4.1 billion years ago. Presumably, if they also allowed simultaneous action of other heat sources, such as unknown amounts of the short-lived radioactive elements, they might have found that Earth's core formed faster. Analysis of atoms in the ancient Greenland rock samples shows that if Earth itself formed as early as 4.55 billion years ago, then the separation of the core material occurred within a few hundred million years — by 4.3 billion years ago. The Soviet researchers pointed out that 2.5 to 2.7 billion-year-old magnetized rocks are known. Since magnetization is believed to be due to currents in the iron core, the core must have existed in something like its present form by at least 2.5 billion years ago.

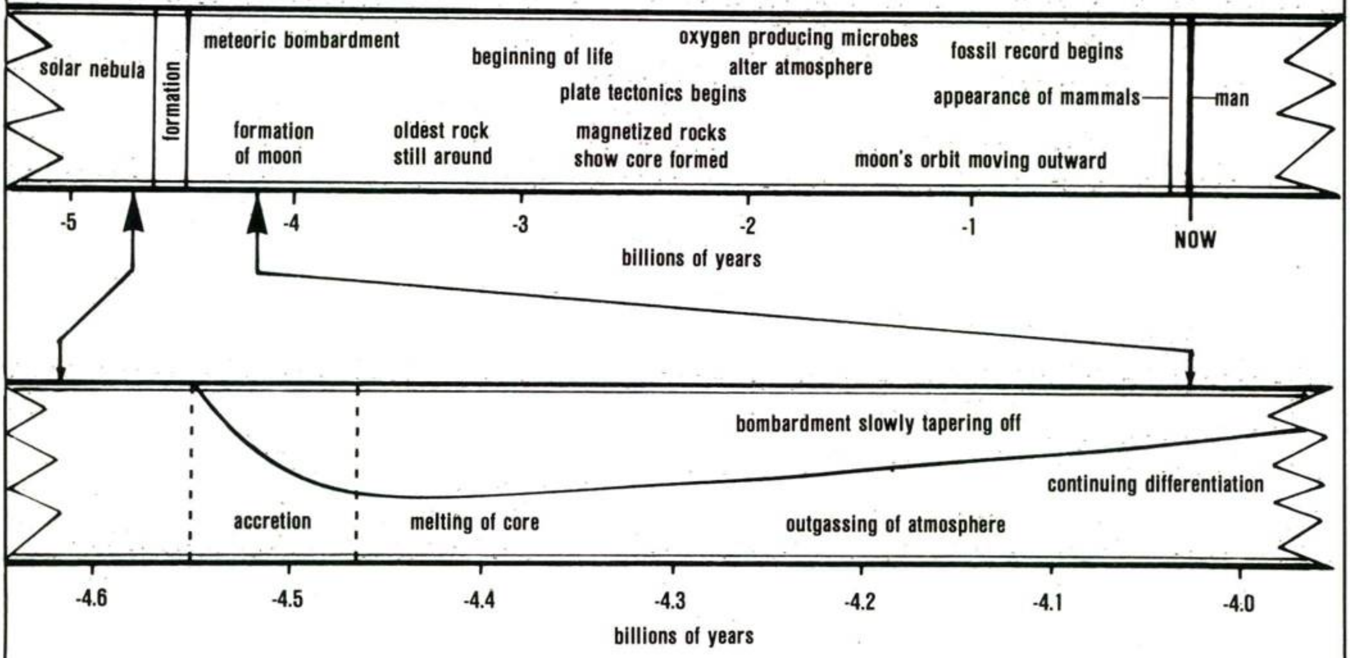
A second pair of Soviet scientists extended these ideas to other planets. For Mercury, Earth and Mars, they assumed that the original homogeneous mixtures contained 69 percent, 33 percent and 16 percent iron, respectively, in keeping with their distances from the sun. After heating, the iron drained to the centers of these smaller planets, and they cooled sooner than the larger ones. The calculations showed that Mercury probably melted and drained all its iron into a core about four billion years ago, and Mars melted and drained some 1.5 billion years ago. But Earth's core, though nearly complete by 2.5 to 4.5 billion years ago, is still molten and has accumulated (according to the calculations) only 86 percent of the available iron. The core may still be growing slowly as geological processes continue today. These calculations agree with the apparent relative ages and geological activity of the surfaces of these planets.

Origin of Earth's Moon

All this relates to another important but mysterious event in Earth's early history: the origin of the moon. We know the moon is now spiraling slowly away from Earth because of tidal forces. In the beginning it must have been closer. Because angular momentum must be conserved, Earth must have spun faster in the past when the moon was closer! Surprisingly, confirmation comes from observation of fossils of marine creatures. Their shells create daily and monthly banded

Early Earth was pounded again and again by impacts from all sizes of infalling material. The largest blasted giant marelike basins; the smallest burned in the atmosphere as meteors still do today. This picture, taken from the rim of Meteor crater in Arizona, shows the devastation created only 20,000 years ago when a small leftover chunk of debris — perhaps the size of a house — impacted. Photograph by William Hartmann.

5 BILLION YEARS OF EARTH'S HISTORY



solar nebula
formation
meteoric bombardment
formation of moon
oldest rock still around
beginning of life
plate tectonics begins
magnetized rocks show core formed
oxygen producing microbes alter atmosphere
moon's orbit moving outward
fossil record begins
appearance of mammals
man
-5
-4
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-1
NOW
billions of years
bombardment slowly tapering off
accretion
melting of core
outgassing of atmosphere
continuing differentiation
-4.6
-4.5
-4.4
-4.3
-4.2
-4.1
-4.0
billions of years

The formation and early history of a planet are surely the most dramatic times in its history. So it is with Earth: Accreting from a cloud of dust, gas and chunks of rock swirling around the primitive sun, the new planet was bombarded for millions of years by cosmic debris, heated internally by the decay of radioactive atoms in its rocks, differentiated as dense iron sank and lighter silicates rose, and finally cloaked in an atmosphere of gaseous volcanic belchings. After those initial years dominated by external astronomical events, Earth settled down to a quieter and longer geologically and biologically influenced history — the fascinating transformation of a hot ball of rock into the planet we know today.

structures. Such fossil organisms show that the day and month were shorter in the past, with a month possibly as short as 17 days some 2.8 billion years ago.

The logical extension of this evidence is that the moon was very close to, or even part of, Earth in the beginning. As long ago as 1900, scientists speculated that the moon might once have been part of Earth. In the original version of the theory, the proto-Earth spun so fast that centrifugal force flung material off the equator to form our satellite. That version collapsed, however, when geophysicists proved that an isolated, homogeneous Earth could not have had enough angular momentum to spin off the moon and then slow down to the present spin rate. More than a half century later, the theory was revived when University of Massachusetts researcher Donald Wise showed that formation of Earth's core could have helped. When a spinning mass pulls its material toward the spin axis, it spins faster, according to the law of conservation of angular momentum. This is why a figure skater spins faster when he pulls in his arms. Thus, with the draining of dense iron toward Earth's center, and the floating of lower density rock to the outer layers, Earth's spin could have increased. This might have triggered an instability that might have led to fission of the moon. However, geophysicists analyzing this model still conclude that the initial angular momentum would be too great for the present conditions we see on Earth. By the time the first Apollo lunar samples arrived, the breakup of the early Earth to form the moon was thus considered a dead theory.

But study of the lunar samples has led more and more scientists to think that the rocks postulated to make up the bulk of the moon are suspiciously like those thought to make up the outer part of Earth's mantle. If true, it may force scientists to conclude that the moon's material was, somehow, torn out of Earth's outer mantle during the early history of Earth — certainly a spectacular happening! A compelling feature of this theory is that it explains the moon's puzzling lack of iron. If the moon formed from material that condensed near Earth's distance from the sun, it should contain as much iron as Earth does. The theory really accounts for the deficiency, postulating that the iron had already drained from the outer mantle toward Earth's core by the time the lunar material was thrown off.

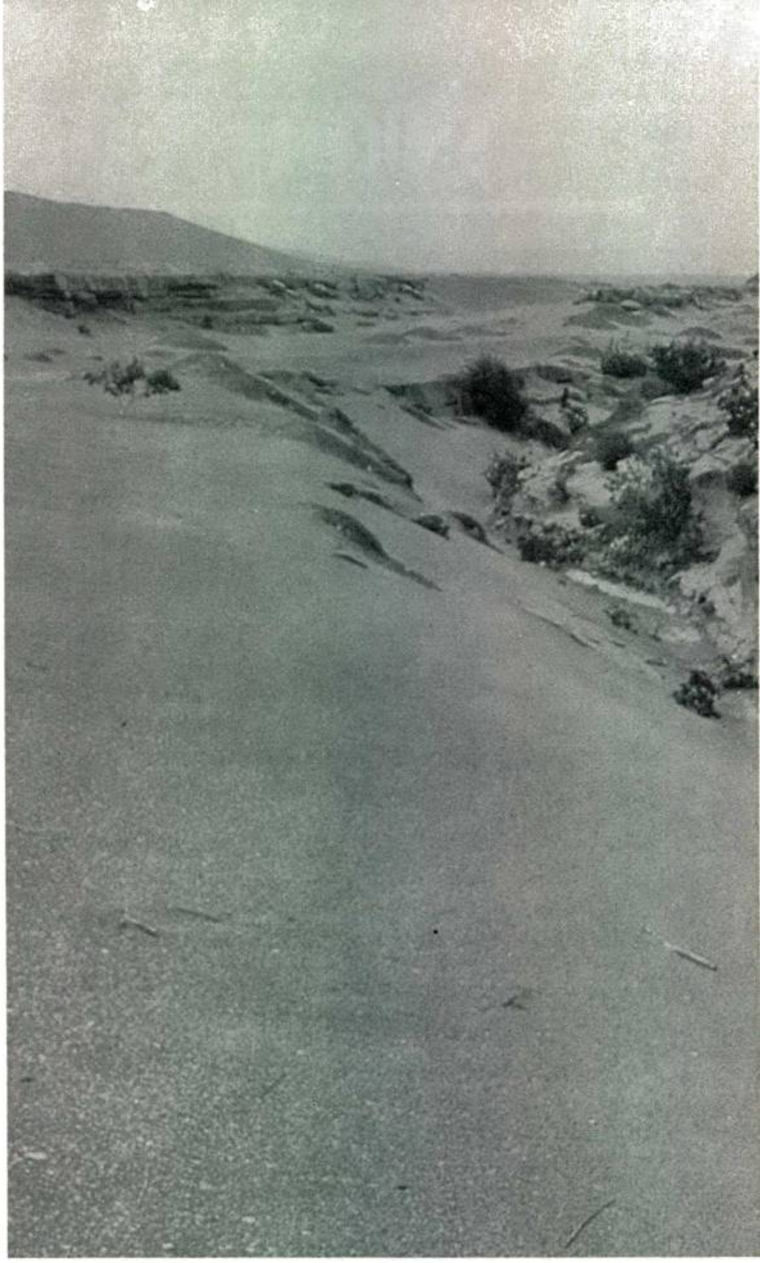
In the face of previous rejection of the fission theory, how could the moon's material have been expelled from Earth? A promising theory was suggested by Donald R. Davis and myself, and independently by A. G. W. Cameron and William Ward. Remember the conditions under which Earth originally formed: a collection of numerous colliding bodies. By the time Earth reached nearly its present size, the second largest preplanetary body in Earth's vicinity could have been quite large —from lunar size to a size approaching that of Mars. If this body hit the rapidly spinning Earth rather late in its growth process— after the iron had started to drain to the center— it could have blasted much upper mantle material into a cloud of hot dust around Earth. The likely high temperature of this cloud would drive off water and other volatile materials, conveniently explaining why the moon is so devoid of water. The moon could have formed from the cloud by accretion processes. Since lunar rocks suggest the moon formed and produced its present surface materials as early as 4.5 to 4.4 billion years ago, this model requires that Earth had formed, begun to drain its iron toward the center, and have been blasted by a planet sized object all within the first 100 million years or so of its existence.

The End of Formation

These ideas bring us to another phase of Earth's early history — the sweepup of interplanetary debris left over after formation of the planets. Regardless of whether this debris contained objects as large as the moon or Mars, it certainly contained objects ranging up to 100 miles (160km) across. We see, in the craters on the moon and on older regions of Earth, the impact scars of these objects. Carnegie Institution dynamicist George Wetherill has calculated the orbital properties and sweepup rates of these objects. The residual material can be characterized by a *half-life* similar to that defined for radioactive elements — the time required for half the population existing at any moment to be swept up by Earth and the moon. They were at first swept up very rapidly: The half-life 4.4 billion years ago was only about 20 million years. By four billion years ago, it had lengthened to 200 million years. As of one billion years ago, the half-life was about one billion years, so that there has been a long "tail" of slow bombardment by meteorites. The record of impacts preserved on the moon agrees with this timescale precisely. Counts of craters in different aged areas show that the cratering was intense four billion years ago, thousands of times more than today, and declined at a rate with a half-life about 200 million years.

Nearby, Earth must have been subject to the same intense early cratering, corresponding to the sweepup of interplanetary debris. The early Earth landscape must have been as dominated by large craters and basins as the four billion-year-old lunar highlands are. In fact, basins even wider and deeper than the 1,000km (600 mile) basin filled by the lunar Mare Imbrium probably existed on early Earth. They would have been surrounded by rugged rims, rings of towering cliffs, and radiating fractured canyons just as the lunar basins are today.

Clearly this type of ancient cratered landscape has vanished. Why? In part, because of erosion, but more fundamentally because Earth's crust and outermost mantle has broken into moving plates. Driven by currents deep in Earth, plates pull continents apart or push them into collisions with one another. The surface rock layers crumple, destroying original relief, dragging some rock down into the mantle, and raising the chaotic mountain ranges that are unique to Earth. Maryland astronomer Herbert Frey has recently shown how the transition from a cratered landscape to today's dynamic plate tectonics may have been aided by the cratering process itself (see "Earth's First Oceans" in this issue). Giant impacts, perhaps four billion years ago or earlier, may have made fundamental inhomogeneities in the original uniform crust. Granite-like surface rocks would have been thrown aside and piled up in some regions (protocontinents?), while deep holes or craters in other regions would expose the upper



Many times in our planet's history, wind and water must have shaped scenes like this eroded wash in the Peruvian desert some 100 miles south of Nasca. Eroded rock forms stand on one side of the channel; sand or fine dust forms the other side. Note that life on Earth can exist in environments as hostile as this. Photograph by William Hartmann.

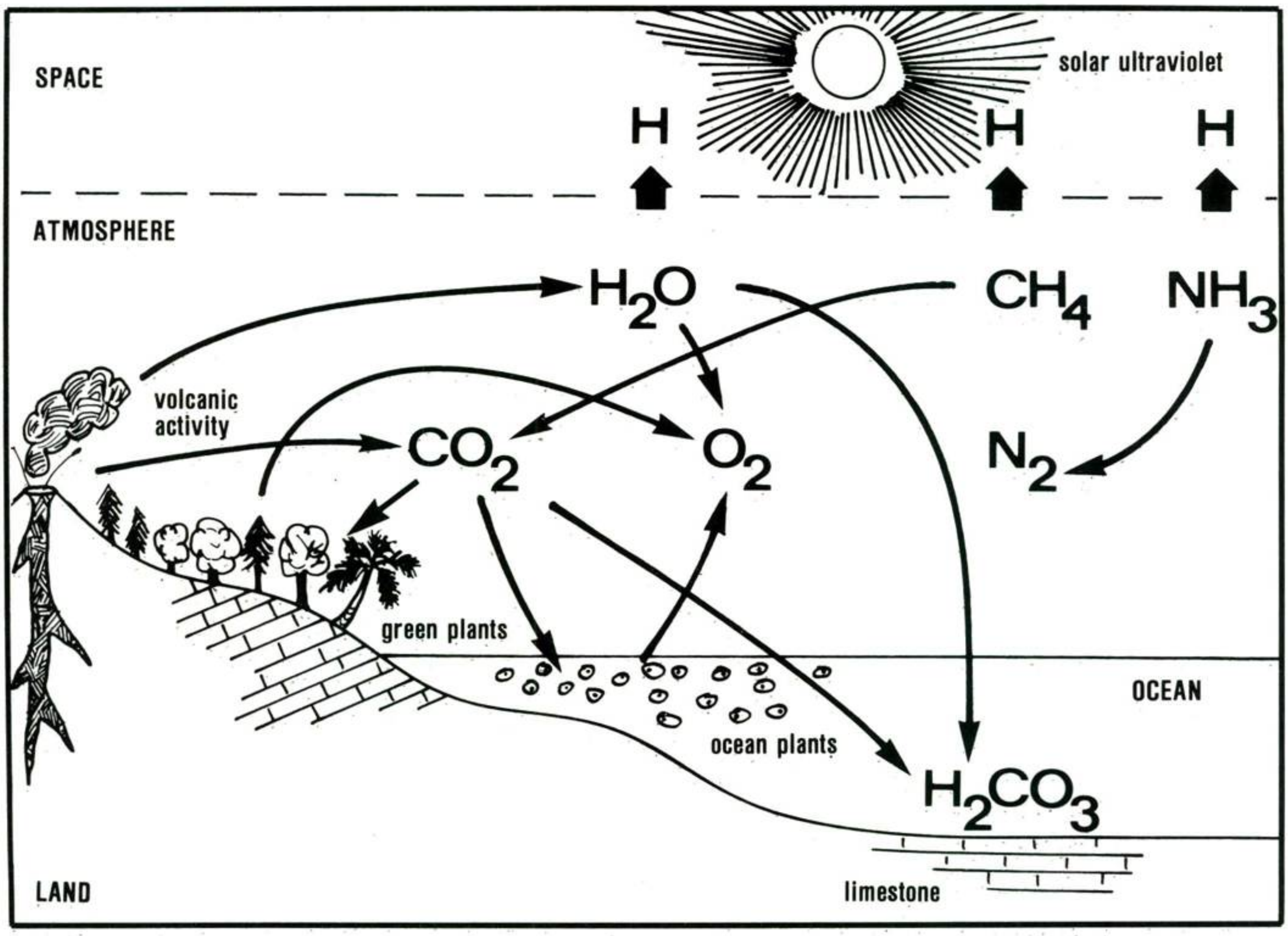
mantle materials. Thermal convection currents — possibly exaggerated in thin crustal regions — may have begun the patterns of rock flow that shape the continental blocks we see today (see "Our Dynamic Planet" in this issue).

Oceans and Air

During all this activity, the atmosphere and oceans were evolving. Most researchers assume the gas initially surrounding Earth was merely a local concentration of the nebular gas from which the sun formed. It was a gas rich in hydrogen, helium and the gaseous compounds that would form as this gas cooled: water (H_2O), methane (CH_4), nitrogen (N_2) and ammonia (NH_3). Above this initial cosmic atmosphere, interplanetary gas was quickly driven away by the solar wind after the solar system formed. The initial atmosphere then began to change. Because lightweight atoms move faster than heavy atoms and molecules, many of the lightest atoms escaped from the atmosphere into space. The lightest gases, such as hydrogen and helium, most quickly evaporated into space. Our moon's lighter gravity allowed more general escape, and *all* the gases escaped. The remaining early terrestrial atmosphere likely was mostly methane.

As yet another consequence of the heating of the interior of the early Earth, new gases were added. Just as boiling of a bowl of oatmeal drives off steam, heating of Earth's interior drove off trapped gases and liquids (a process called *outgassing*).

In the 1950s and 1960s, geochemical studies showed that most of the evolution from the initial to the present atmosphere can be explained by adding volcanic gases outgassed from Earth in two stages. The first stage lasted as long as the mantle still had large amounts of metallic iron — probably only during the first 100 billion years or so. The free iron chemically combined with oxygen and removed it from the outgoing gas, so that volcanic gases were initially rich in methane, hydrogen, hydrogen sulfide (H_2S), nitrogen, and related gases. The second stage came after much of the mantle's iron had drained away or been oxidized, so that oxygen-rich gases could escape. These included water and carbon dioxide (CO_2), along with sulfur and



Evolution of Earth's present life supporting atmosphere depended on sunlight, oceans, green plants and, of course, the right combination of initial conditions! The early atmosphere lost hydrogen to space, and later lost carbon dioxide to the formation of rocks. Green plants and microbes brought about an amazing transformation: the addition of large quantities of oxygen through photosynthesis!

nitrogen. The volcanic gases originating in the mantle and erupting today in Hawaiian volcanos are more than 80 percent (by weight) water and carbon dioxide. By adding water and carbon dioxide to the earlier atmosphere of nitrogen and methane, it begins to look (at least a little) like the present environment: an atmosphere of nitrogen and oxygen with oceans and rainstorms of water.

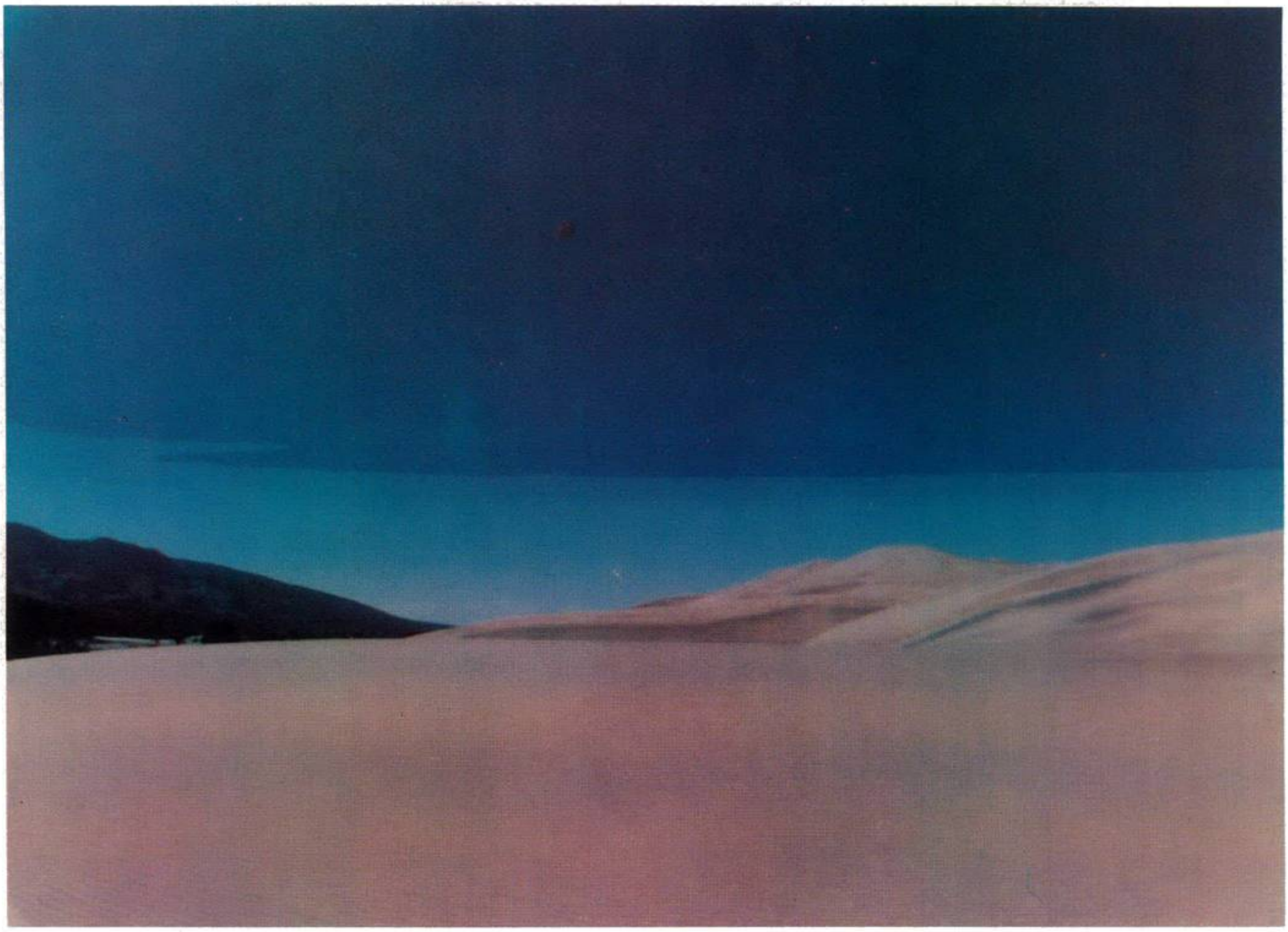
The early atmosphere contained huge amounts of hydrogen bound up in methane. When energetic solar ultraviolet light broke up hydrogen bearing molecules such as methane, hydrogen atoms were freed; liberated, they soon escaped into interplanetary space, thus ultimately removing the hydrogen.

What about the carbon dioxide? If volcanos produced vast amounts, what happened to it? Earth does, in fact, have vast amounts of carbon dioxide, but it is hidden in rocks, transformed to carbonate minerals. Whenever carbon dioxide gas outgassed from volcanos, most of it dissolved in ocean waters, forming a weak carbonic acid like that in carbonated beverages. But the carbonic acid reacted in turn with the surrounding silicate rocks to form insoluble carbonates and quartz minerals, which became rock.

And where did the oxygen come from? Some came when solar ultraviolet light broke up water or carbon dioxide, liberating oxygen atoms. But most scientists think the bulk of it has been added slowly over the eons since plant life evolved. Plants "inhale" carbon dioxide and "exhale" oxygen. The oxygen content has probably increased steadily from perhaps three billion years ago—when life began — to the present.

In short, the atmosphere's evolution involved five major steps: 1) losing hydrogen into space; 2) outgassing of water, carbon dioxide and nitrogen; 3) precipitation of water; 4) burial of the carbon dioxide, and 5) biological enrichment of oxygen.

The atmospheric processes of the early Earth shed important light on the relation of Earth to other terrestrial planets. Why do Mars and Venus have atmospheres completely dominated by carbon dioxide rather than nitrogen and oxygen like Earth? Suppose only that water molecules on them did not form oceans; water may have been frozen on Mars and broken apart by ultraviolet sunlight on Venus. (Much may also have escaped in Mars' lighter gravity.) When Martian or Venusian volcanos dumped water and carbon dioxide into the atmosphere, the water tended to be lost. The carbon



If Viking had landed on Earth instead of Mars, what scene might it have transmitted back? Assuming that flight controllers searched for smooth terrain — and succeeded in avoiding the oceans that cover 3/4 of Earth's surface — this scene might have resulted! This picture was taken with Viking cameras in the Mojave desert as a test of the Viking camera system. NASA photograph.

dioxide then could not dissolve and get converted into rock. In the absence of oceans, life could not evolve and oxygen was never added. Thus carbon dioxide — not water or oxygen — came to dominate the atmospheres of both. Venus and Earth, the sister planets, both have about 90 times Earth's atmosphere masses of carbon dioxide. On Venus it's still a gas; on Earth it's buried in rocks.

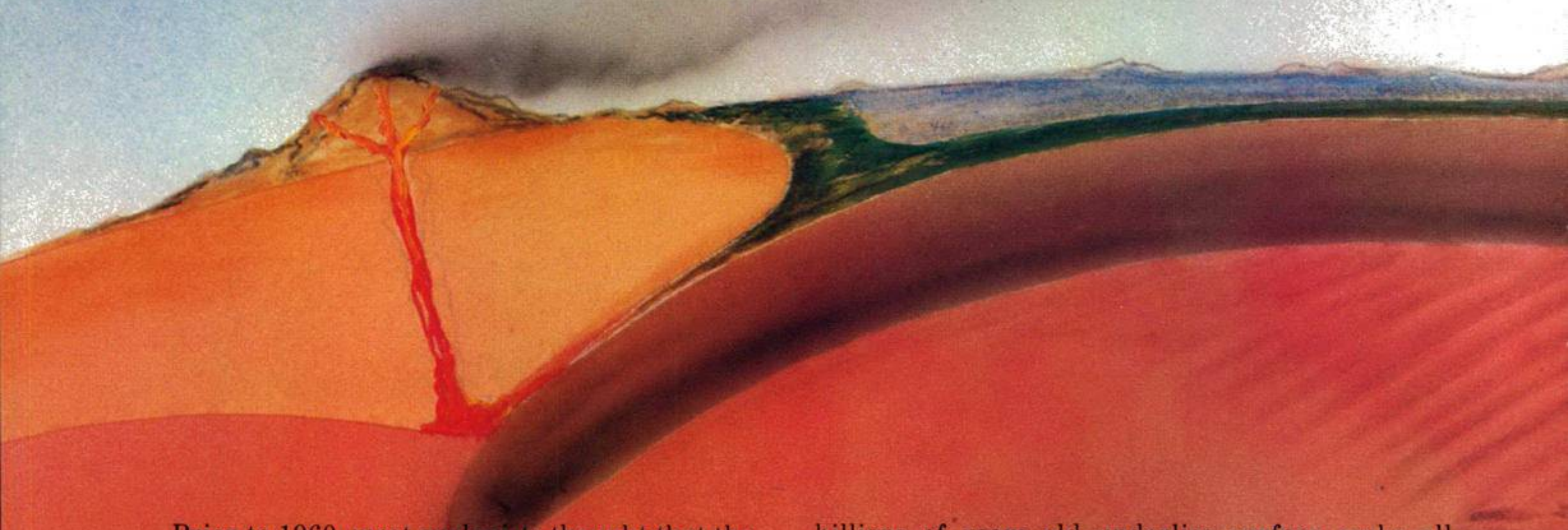
The Consensus Genesis

During its early history — its first billion years —Earth was very different from what it is today, yet it contained the seeds of the environment we know now. Mineral condensation and accretion in the solar nebula gave the basic composition and mass by about 4.5 billion years ago. Heating and melting drained the iron to the center and concentrated lighter, iron-poor rocks near the surface by perhaps 4.4 billion years ago. A gigantic collision in this interval may have played some role in putting the moon in our sky. Continued smaller collisions cratered Earth and the moon and swept interplanetary space relatively free of debris, so that today we are hit only occasionally. Thermal evolution — and perhaps impacts — broke the surface rocks into plates that define and shift continents. Volcanic outgassing, life, and other processes altered the atmosphere to its present form.

Astronomers and those interested in space exploration should remember that much of Earth's early history was dominated by astronomical processes and clarified by astronomical studies. The datable fossil record, on which most traditional geology has been based, extends over only the last 600 million years. Indeed, if the whole biography of Earth was reduced to a book 100 pages long, the lifeless first billion years would occupy the first 22 pages. Since very few terrestrial rocks survive from that era, much of the evidence comes from study of the moon, meteorites and other planets. Astronomy has helped us to understand Earth. The description of life forms substantial enough to have left fossils (and thus define the conventional geological timescale) would occupy only the last 13 pages. And human beings would be mentioned only in the last sentence!

William K. Hartmann is a senior scientist at the Planetary Science Institute in Tucson, Ariz. His research interests include planetary origins and evolution, cratering, the solar system environment and astroarcheology. Hartmann has recently written **Astronomy: The Cosmic Journey**, *a textbook published by Wadsworth Publishing Company.*

Our Dynamic Planet



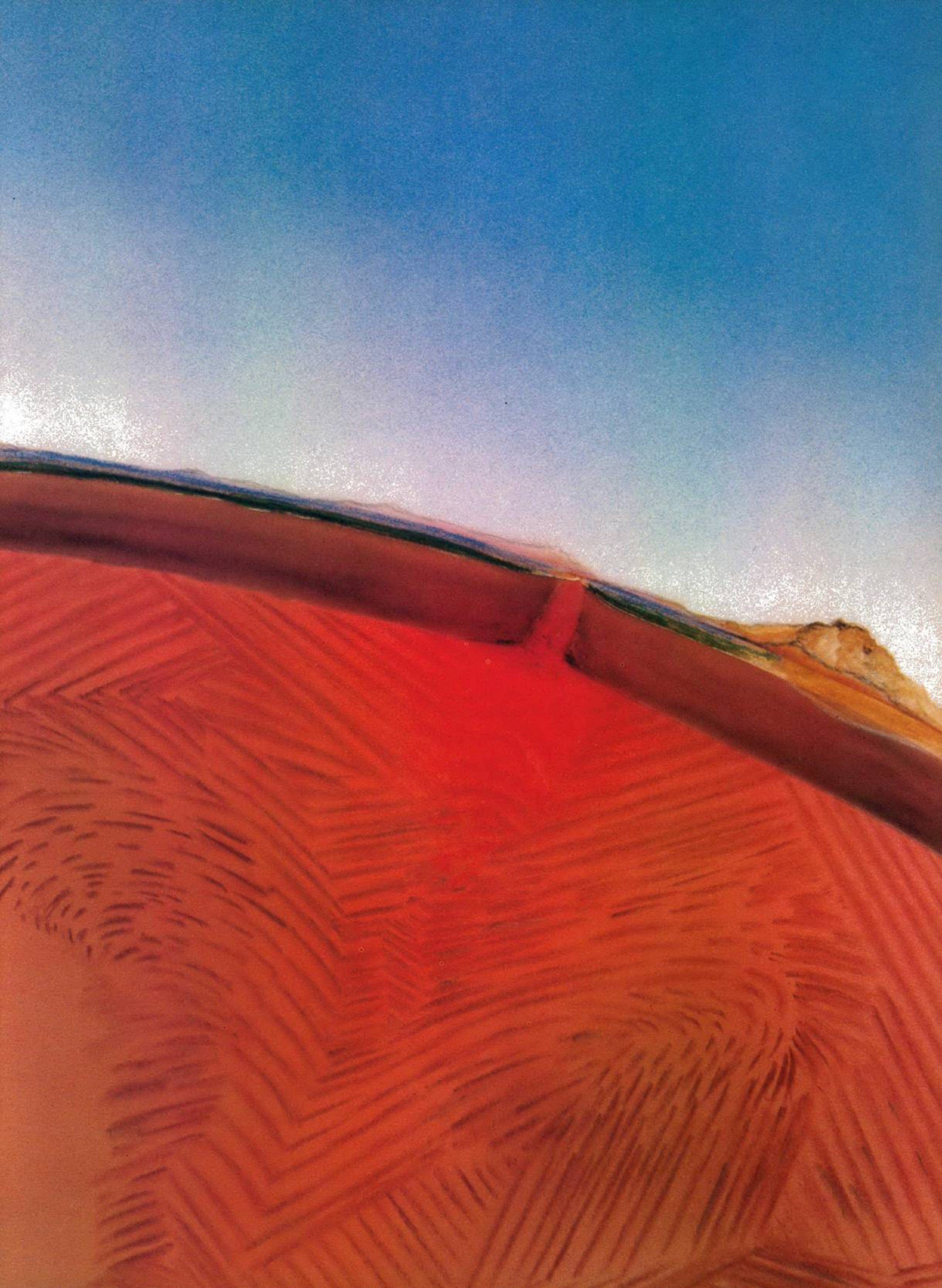
Prior to 1960, most geologists thought that the oceans and continents of Earth were fixed. While many acknowledged flaws in the overall picture of Earth — disconcerting anomalies in the fossil record, provocative and inexplicable similarities in the shapes of South America and Africa, volcanic activity along continental margins, and island arcs and deep ocean trenches — few supported the notion of continental drift. If the continents did indeed move, they reasoned, then we should see wakes or trails in the ocean floors, plowed by the continental motion. No such traces were seen, so there had to be other explanations for the evidence.

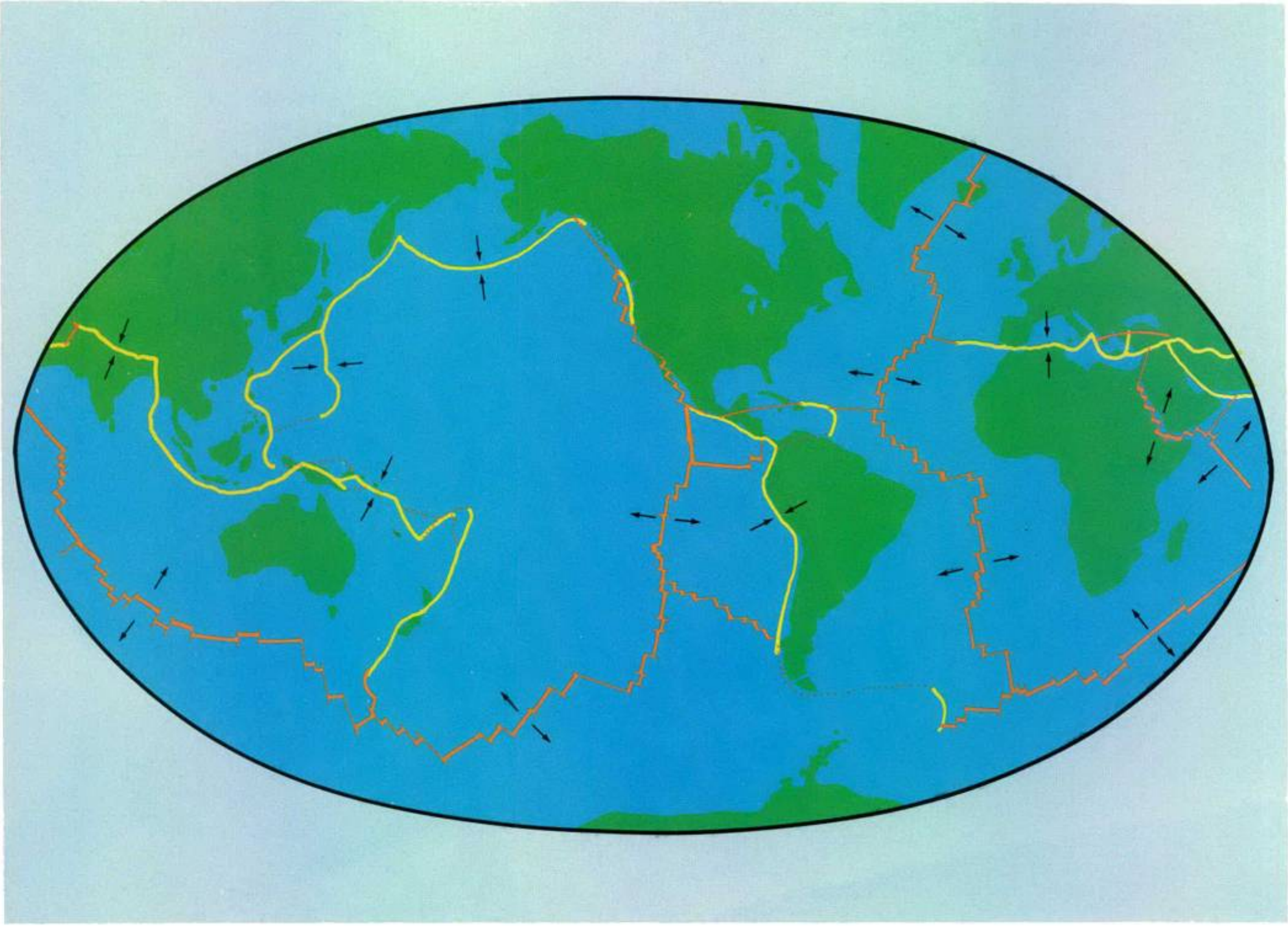
Following World War II, oceanic exploration began in earnest. Most — in fact almost all — of our knowledge of Earth's surface previously came from studying the dry 1/4 of the planetary surface, but new technologies and new sources of research funding finally ended the neglect of ocean geology. The oceans, as became evident in the 1950s and 1960s, are far more than just low places where water collects.

The crust of planet Earth is low in these areas — averaging two to three miles lower than continental land surfaces. The oceans turned out to display simpler forms than anticipated — and that in itself was puzzling. Above all else, the ocean floor turned out to be young. While continental rock up to billions of years old underlies surface rocks all around the world, most oceanic floor is less than 100 million years old, and none is older than 200 million years. The oceans conceal vast underwater mountain ranges: The Atlantic is split nearly pole to pole by a vast midocean ridge. The complex sedimenting, layering and folding behavior of the continents was missing.

In 1960 the pieces began to fall together. Rather than continents that ground across the ocean bottoms, the idea that continents might be carried along "like coal on a conveyor belt" opened the way to new investigations. Midocean ridges revealed their secret in 1964: They are the sites of the formation of new ocean crust. The "conveyor belt" of oceanic floor grew in the ridges. The deep trenches suddenly made sense: Old crust was swallowed up in them as the "conveyor belt" plunged down again. During the decade that followed, more and more evidence accumulated that continental drift does indeed occur, but in the modern sophisticated guise of *plate techtonics*, a powerful theory already

The crust of Earth is the living skin of a planet with an active interior — not a dead shell of cold rock — consisting of a dozen continent sized "plates" that carry the continents on their backs. Plates open and close mighty oceans and control the formation and location of the mineral wealth of the planet. Artwork by Mark Paternostro.





Running down the midocean ridges and along the margins of the continents, divisions between the lithospheric plates of Earth's crust are geologically active zones — places where earthquakes, volcanos, mountain ranges and deep oceanic trenches lie. Plate motions are slow — mere inches per year — but the effects have totally changed Earth's surface several times over in the last billion years.

yielding economic benefits in petroleum and mineral exploration.

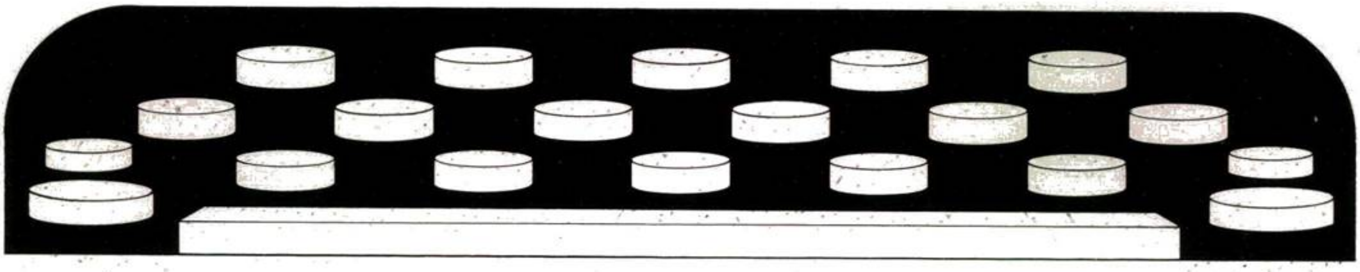
Plate techtonics holds that Earth's surface is divided into roughly 12 "plates", or rigid slabs of crust. Plates may be largely continental crust, a mixture of continent and ocean floor, or entirely ocean floor. Driven by forces deep in the interior — possibly rising plumes of hot rock from deep inside Earth — the plates move slowly across the surface and grind against each other. At the midocean ridge sites, new ocean floor is created; in the deep trenches along the margins of some continents (such as the western coast of South America), old crust is consumed — subducted — and is sinking back into Earth.

The motion of the plates is slow — from 1 to 8 inches (2 to 20cm) per year. The Atlantic has been opening for about 70 million years at an average rate of about 3 inches (7cm) per year. The west coast of the United States is slowly overriding another plate. In the process, the faults of the west coast pose an earthquake danger. The subcontinent of India has — and is — colliding with Asia, raising the rocky wrinkles we call the Himalayan Mountains. The process is so slow that a collision between continents went nearly unnoticed by the world's geologists for 100 years.

Geologists still don't know exactly what drives the motion of the continents. While they probe the depths of Earth for answers, astronomers and planetary scientists are looking outward in search of answers too. The lunar laser ranging experiment (which you might have seen set up on the moon via television from Apollo) enables astronomer/geologists to measure not only the distance to the moon, but also the distance between Earth based ranging stations. It should be possible — soon — to measure the motion of the plates directly.

To planetary scientists too, plate techtonics offers fundamental insights into the interior processes of the planets. Earth has plates, but the moon and Mercury do not. Why? And what about Mars and Venus — they're more Earthlike than the moon and Mercury. Do they have active plate techtonics? At present, the answer seems to be: Mars, no; Venus, maybe!

The best currently available sourcebook about terrestrial plate techtonics is **Continents Adrift and Continents Aground** *(published by W.H. Freeman & Co.), with introductions by noted geologist J. Tuzo Wilson. The book contains articles reprinted from* **Scientific American** *that retrace the story of this fascinating revolution in geological thinking.*



IN FOCUS

Sir / The possible exploitation of our solar system ("Terraforming", ASTRONOMY, May 1978) seems awesome in its potential consequences and narrow in its focus on planetary and human needs. All those atomics blasting Mars, cooking the Martian poles, gobbling up asteroids, dismantling the mantles of planets...well, that sure makes me wonder what's in store for humankind after those consumptive rumbles, spins and gasps. Perhaps Andromeda....

The means of terraforming has the ring of technological growth separate from any notion of universal and human growth. The consequences of terraforming are evident here today on Earth: a haunting reflection of the strip mined East and West, of the rubble of oxygen bottles left on the South Col on Everest, of the still radioactive post-"A" test South Pacific isles, and of declining terrestrial quality inclusive of we inhabitants. The ghost of nihilistic and technological dualism leaves something to be desired in my imagination. James Oberg's imaginative picture has stimulated my thinking about the choices — and to that end I feel gratitude. If Earth folks choose a path that makes "living on Earth as obsolete as living in trees", then I wish that the final dying gasp of the sun will beat the escapees to the perimeter of their flight. As an alternative, why don't we just gently tread and wisely use on our journey through the solar system and beyond?

ROGER MERCHANT
Georgetown, Ky.

Sir / I recently read about the Mt. Hopkins multiple mirror telescope for use at the Smithsonian Observatory. I figure if the idea works so well, perhaps I could build one.

My idea is to use seven six-inch mirrors. If I use f/8 mirrors, I could have the light gathering power of a 16 inch telescope in a 48 inch focal length! Next, could I get the system to work using Cassegrain type mirrors? Can I get the mirrors to align properly with the secondary mirror? I could probably order seven mirrors, but only one secondary. My main problem would be getting all seven mirrors to collimate properly and still obtain a good image without any form of aberration.

JACK BRISBIN
Canton, Mich.

Mr. Brisbin / The multiple mirror telescope (MMT) is a special professional design and unfortunately not one that can be built easily at home.

Most articles of a popular nature do not reveal that it requires thousands of dollars in special optical equipment to align the many mirrors of the Hopkins assembly to achieve the final expected performance. Both visual and laser optics are used to achieve the high quality images. One type of special prism used in the MMT (and six are needed) costs about $1,000 each!

If it were possible to achieve results, we'd be most pleased to help and advise in any way, but as you may now realize, it's not a practical project.

You're to be congratulated on your enthusiasm and interest in new designs and ideas. Please don't be discouraged but keep trying to find a system that would be unusual and rewarding to fabricate! Robert E. Cox.

Sir / I'm presently building a 10 inch f/5.6 reflector from commercial parts, and am wondering if the mount on page 53 (ASTRONOMY, January 1978) would work for my telescope. I live in the country, so portability isn't a problem.

DALE R. FLIPPO
Harrison, Ark.

Mr. Flippo / You'll have to scale the design up in size somewhat to accomodate your larger telescope, of course, but it will work.

As Richard Berry mentioned in the article on mountings, for a 10 inch instrument you should use axes having a pipe diameter of at least 2-1/2 inches.

For so large an instrument, it's advisable to be sure the bolts used to hold the parts are securely tightened and checked periodically to be sure they don't loosen up.

If cost is not a problem, you can have machined parts made and use bearings on the axes for smooth and regular motion. The mounting was presented so those with little or no knowledge of mechanical work could make a good mounting. Mechanically minded telescope makers with plenty of tools can make many changes in the materials to good advantage. Robert E. Cox

Sir / I just bought a Newtonian reflecting telescope. I was wondering which kind of eyepiece I should add for good viewing. I already have a 1-1/2 inch and a 1/2 inch (but not the best).

Also, where can I buy good filters for lunar and solar observing?

SCOTT SHAFER
Ida, Mich.

Mr. Shafer / Eyepiece focal lengths should be chosen to give a smooth range of powers from lowest to highest; thus you'll find that a 1 inch (25mm), a 16mm, and an 8mm will round out your selection of powers nicely. Generally, if you test many different brands of eyepieces side by side, you'll find they are pretty much the same. More important is the type. With reflectors, orthoscopic eyepieces usually perform well, though Erfles (with their wide fields) are nice at low powers. Refractors having long focal ratios (such as f/15) are not fussy; even inexpensive Ramsden, Huygens and Kellner eyepieces perform well.

Sir / While reading on the connection between astronomy and the "ice ages", I encountered the following numbers in ASTRONOMY referring to the length of galactic years:

April 1976, page 21: galactic year = 200 million years
January 1976, page 63: galactic year = 303 million years
September 1975, page 57: galactic year = 500 million years

I would appreciate any information you might have as to the generally accepted figure for the galactic year.

ROBERT J. STATES
New York, N.Y.

Mr. States / The galactic year is difficult to determine because the sun's distance from the center of the galaxy is not accurately known. In the last decade, figures between 8,000 and 10,000 parsecs (26,000 to 33,000 light-years) have been used. The best figure is probably a compromise figure (9,000 parsecs). Since the sun travels around the galactic center at 230 kilometers per second, the galactic year is some 230 million years long. The spiral arm pattern of the galaxy rotates once every 500 million years, so the sun overtakes and passes through a spiral arm every few hundred million years.

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James Hervat
- ☐ JH-01 Pluto
  February 1977, pp. 20 & 21
- ☐ JH-02 Uranus From Voyager
  February 1977, pp. 6 & 7
- ☐ JH-03 Formation of Mare Imbrium
  September 1976, pp. 6 & 7

Anne Norcia
- ☐ AN-01 Mercury Terraformed
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Perseids Perk While Planets Lull

by

Robert Burnham

The pickings are a little slim this month for planet watchers. Both Mercury and Saturn are close to the sun this month and Mars is dim and distant. But there will be both a morning and evening "star" all month — Venus in the evening and Jupiter in the morning. On top of that, there's one of the year's best meteor showers and a striking conjunction of two planets and the moon.

Mercury

The solar system's innermost planet is too close to the sun to be seen easily this month; it comes to inferior conjunction on the 18th. You'll have better luck next month when the planet is at its greatest western elongation.

Venus

On the 29th, Venus reaches greatest eastern elongation, but it won't be a very favorable one because the angle the ecliptic (the path the sun and planets travel across the sky) makes with the horizon is very small. Even though it's 46 degrees east of the sun, the elevation above the horizon will be only 18 degrees. (That's about the size of a paperback novel's long dimension when held at arm's length.) Its phase in a telescope looks very much like a first quarter moon.

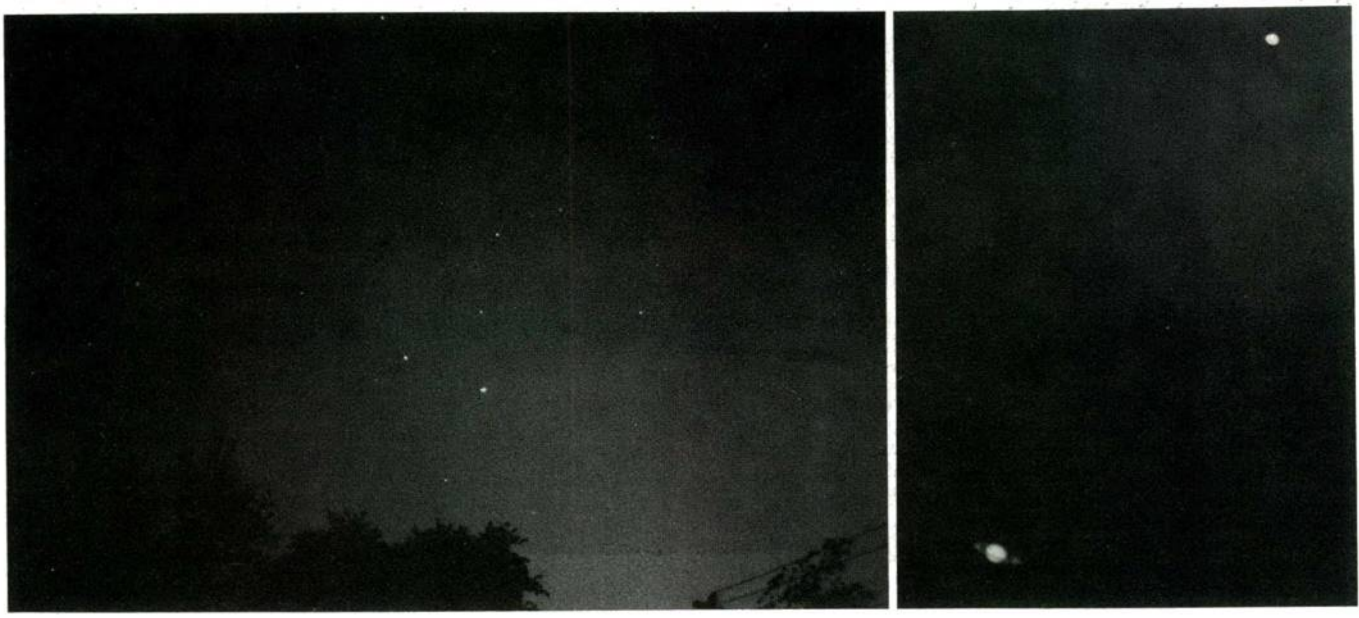
On the evening of the 7th, there will be a striking conjunction of the moon, Mars and Venus. In the southwest part of the sky, the four day old moon will be close to +1.6 magnitude Mars and -3.8 magnitude Venus. At sunset on the 7th, the grouping will be about 20 degrees above the horizon, but you'll have to wait a bit until the sky gets dark enough to show Mars. An hour after sunset the elevation will be down to only 10 degrees, so get set up and work fast on your picture-taking! Be sure to send your best results to ASTRONOMY.

Mars

Mars is fading into the distance this month and will continue receding for the rest of the year. Mars was at its brightest in January when it was at opposition. The next time the planet is at opposition is in 1980.

Through the month, the planet's distance from Earth increases by about 13-1/2 million miles — from 191

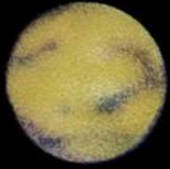
Below: This pair of photos show the close approach of Saturn and Mars (1/10 degree separation) which occurred on June 4. The shot on the left shows the position of the pair (to the right of Regulus) in the constellation Leo. This is a 20 second exposure on Tri-X film taken with a 35mm camera and a 35mm lens mounted on a tripod. The photo at right — showing Saturn's rings and the gibbous phase of Mars — was taken with an eight inch f/5 Newtonian applying the afocal system to obtain an overall f-ratio of 63.5. Tri-X film was used for the 1/2 second exposure. Both photos were enlarged four times. Photographs by Bob Kimmel. Opposite, top: The delicate wisp of a 21-hour-old moon joins Venus (top) and Mercury in this 1/2 second exposure on Ektachrome film (ASA 200) taken with a 300mm telephoto at f/5.5. Photograph by Clifford Newman. Opposite, bottom: Venus and a 31-hour-old moon enhance the beauty of evening twilight's glow. This shot is a three second exposure on Fuji 100 film using a 135mm lens at f/2.8 on a Yashica SLR. Photograph by Ron Gattie.

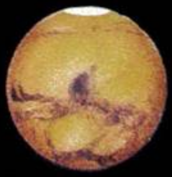


Planet Finder

Ⓒ Ceres

Aug.	1	15
R.A.	$18^{h}55^{m}$	$18^{h}47^{m}$
Dec.	-30°56'	-31°15'
Mag.	+7.2	+7.3





Ⓐ Mercury

Aug.	1
R.A.	$10^{h}12^{m}$
Dec.	+7°50'
Mag.	+1.1

Ⓑ Mercury

Aug.	15
R.A.	$9^{h}56^{m}$
Dec.	+7°23'
Mag.	+2.5

Ⓜ Mars

Aug.	1	15
R.A.	$11^{h}53^{m}$	$12^{h}24^{m}$
Dec.	+1°20'	-2°17'
Mag.	+1.7	+1.8

Ⓝ Neptune

Aug.	15
R.A.	$16^{h}58^{m}$
Dec.	-21°12'
Mag.	+7.7

SUN

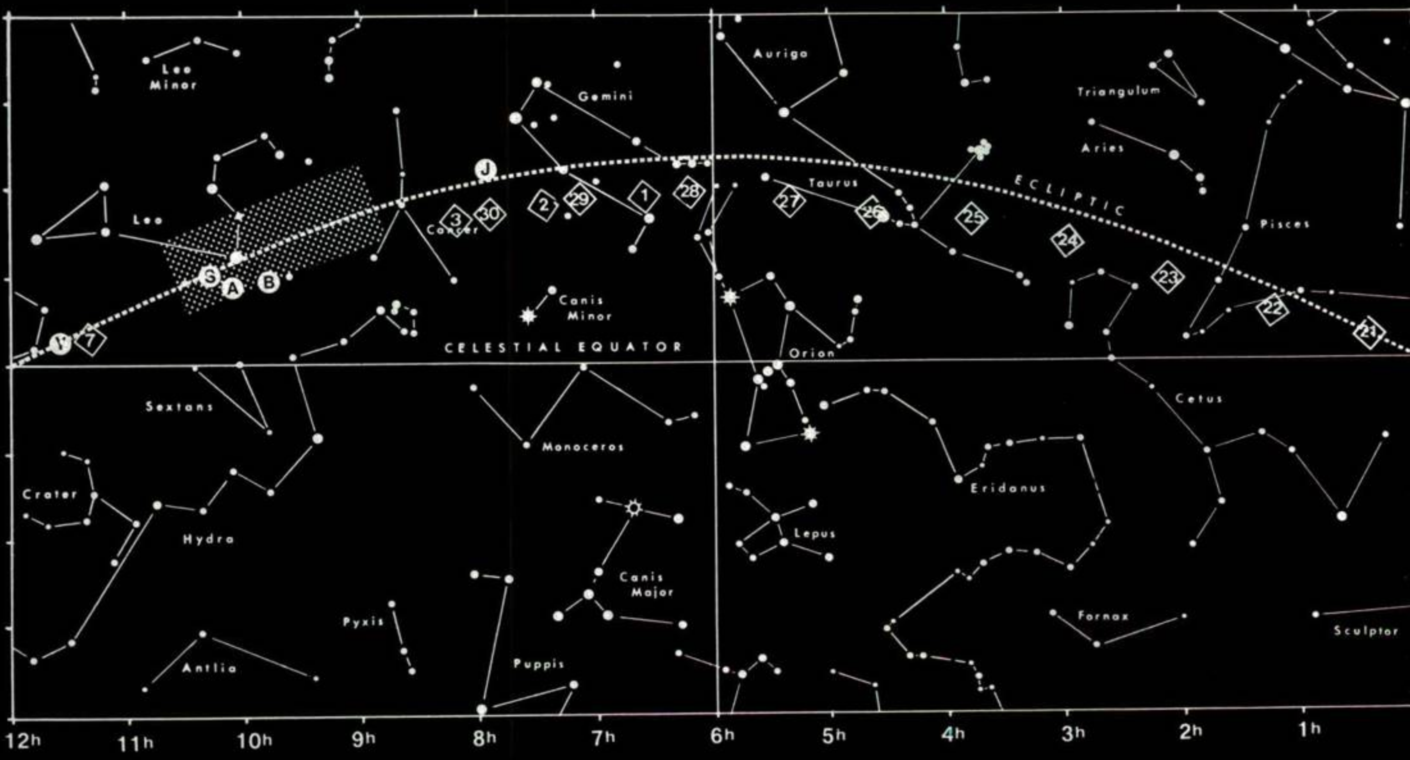
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Aug.	1	15
R.A.	$10^{h}12^{m}$	$10^{h}19^{m}$
Dec.	+12°35'	+11°58'
Mag.	+0.9	+0.9

Ⓤ Uranus

Aug.	15
R.A.	$14^{h}40^{m}$
Dec.	-15°15'
Mag.	+5.7


Leo Minor
Leo
Gemini
Cancer
Canis Minor
Auriga
Taurus
Triangulum
Aries
Pisces
Orion
ECLIPTIC
CELESTIAL EQUATOR
Sextans
Crater
Hydra
Monoceros
Canis Major
Pyxis
Antlia
Puppis
Lepus
Eridanus
Cetus
Fornax
Sculptor
J
S
A
B
7
3
30
2
29
1
28
27
26
25
24
23
22
21
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

August 1978

Ⓥ **Vesta**

Aug.	1	15
R.A.	16h26m	16h35m
Dec.	-19°34'	-20°50'
Mag.	+6.1	+6.3

Ⓙ **Jupiter**

Aug.	1	15
R.A.	7h37m	7h50m
Dec.	+21°42'	+21°12'
Mag.	-1.4	-1.4

Ⓨ **Venus**

Aug.	1
R.A.	11h32m
Dec.	+3°25'
Mag.	-3.7

Ⓩ **Venus**

Aug.	15
R.A.	12h25m
Dec.	-3°33'
Mag.	-3.8

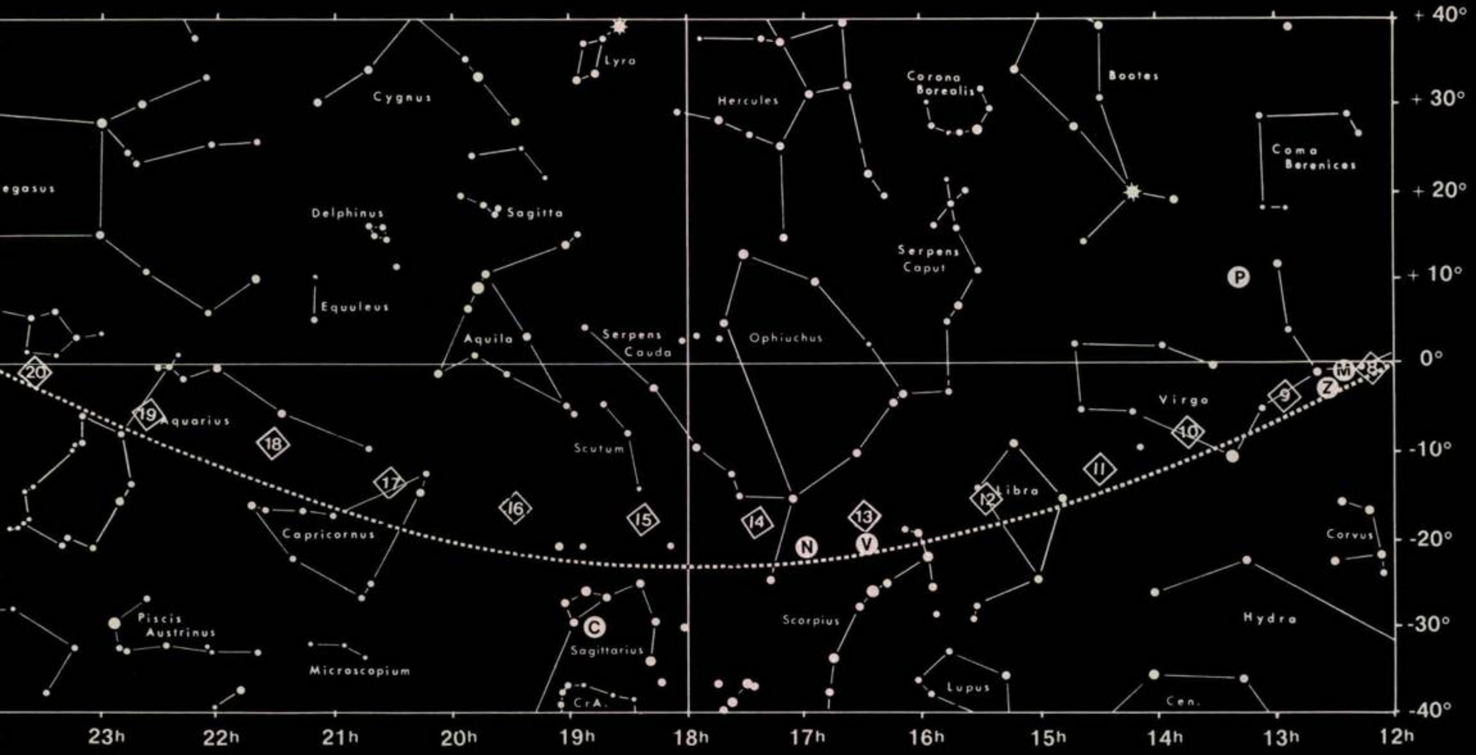
Ⓟ **Pluto**

Aug.	15
R.A.	13h18m
Dec.	+9°50'
Mag.	+14

First Quarter
August 11

Full Moon
August 18

Last Quarter
August 25


+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
egasus
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Equuleus
Serpens Caput
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Corvus
Scorpius
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA.
Cen.
P
M
Z
N
V
C
8
9
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17
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19
20

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

Top left: The elusive planet Mercury (top) is shown here with Venus in this 10 second exposure on Kodachrome (ASA 25) using a 135mm lens. Photograph by Andre Ringuette. Top right: On April 28, 1978, one of the largest flares in recent years erupted on the sun, resulting in many auroral displays such as this one photographed on May 2. According to the photographer, the aurora extended 90 degrees horizontally, upward to 70 degrees in altitude, and lasted for over an hour. He also mentioned that aurorae of this extent are seldom seen at this latitude (39 degrees north). The photo, taken from Middlesburg, Va., is a 20 second exposure on Ektachrome (ASA 64) using a 35mm camera at f/2.8. Photograph by Larry Bohlayer.

million miles to 204 million — losing 1/10 magnitude in brilliance as it goes. Telescopically the disk shrinks from 4.5 seconds of arc to 4.2, which makes for very little planetary detail. You'll be lucky if you see much more than an orange ball! It's now early summer for the Martian northern hemisphere since the sun reached local solstice on May 22 (Earth date). The Martian seasons last about twice as long as Earth's, which means that autumn won't start on Mars until our Nov. 23.

Jupiter

You'll have to be an early bird to catch Jupiter this month. In eastern Gemini for most of the month, crossing into Cancer on the 23rd, the giant planet shines at magnitude -1.4 throughout August. You'll do best to look for it later in the month since at the beginning it's only 17 degrees west of the sun. By the end of the month the separation has increased to 45 degrees, putting it well up in the east before sunrise.

Jupiter's disk has a distinctly flattened shape as even low powers will reveal. Measuring 32 seconds of arc wide at the equator by 30 seconds high over the poles, the flattening is

Upcoming Events for September

2	New Moon
4	Mercury at greatest western elongation
5	Mars 2 degrees south of moon
6	Venus 6 degrees south of moon
8	Mars 2 degrees north of Spica
9	First Quarter Moon
16	Full Moon
22	Occultation of Aldebaran
23	Equinox — autumn begins
24	Last Quarter Moon
30	Mercury at superior conjunction

This will be a favorable elongation of Mercury, even though the planet won't be any higher at sunrise on Sept. 4 than 16 degrees above the horizon. You'll need a clear eastern horizon and no clouds or haze.

Venus is a glorious sight, shining at magnitude -4.2 in the southwestern sky and setting about 1-1/2 hours after sunset. Mars, too, is in the southwestern sky, but it's much more difficult to see than Venus. At sunset Mars is 12 degrees above the horizon at magnitude +1.8. To find Jupiter we must shift from the evening to the morning skies. At magnitude -1.5, the planet rises 4-1/2 hours before the sun and is high in the southeast at sunrise. Saturn is also in the morning sky and can be found very low above the eastern horizon just before sunrise.

The occultation of Aldebaran will be visible from nearly all of the contiguous 48 states, as well as the southern parts of the Canadian provinces. The only persons to miss out on it will be those living in Texas south of Corpus Christi, and in Florida below the 28 degree parallel, approximately. Most of Alaska will miss it, but Hawaii won't.

Catch a Perseid!

If you've ever watched the sky for any length of time, you've probably seen a meteor or "shooting star". Flashing quickly and unexpectedly across some part of the sky, they are always attention grabbers.

The Perseid shower is probably the best one of all. (It's called "Perseid" because its radiant lies in the constellation Perseus at right ascension 3 hours, declination 58 degrees.) The meteors are fast, averaging 40 miles per second, and the number of meteors has remained pretty constant over the years at 50 per hour. In some years moonlight has drowned out the shower, but this year the interference won't be too bad since the moon will be near first quarter.

You can easily observe them with the naked eye, and a dark sky with a clear view to the northeast. The shower activity spreads out over several days, so start looking for the Perseids early in the month. You won't see many, but they'll be there. You can tell the Perseids from a sporadic meteor by tracing the streak back on the sky to see if it comes from the radiant. The radiant, the point from which the meteors seem to originate, is just a perspective effect. In reality, the meteoric material circles the sun in parallel orbits.

The shower peaks rather rapidly: On the eight days before the 12th and three days after, the shower is only 1/10 as strong as on the night of Aug. 11-12, the peak time. Even a day on either side of the 12th cuts the number of meteors to half the peak rate.

For two reasons, you you'll have to wait till after midnight to see the most meteors. First, the radiant is higher, so you are looking through a thinner layer of atmosphere (and you don't miss the meteors that zip below the horizon); secondly, the hemisphere of Earth between midnight and noon is the "forward" one relative to our orbit around the sun. It plows ahead through the swarm, making the meteor rate higher on the leading hemisphere.

While it's fun just to sit and watch, there are several things you can do to improve your knowledge about meteors. Get yourself a lawn chair, a star atlas (such as Norton's), a clock, a flashlight with red tissue over the lens, and a piece of white string about two to three feet long. Set up so that you can watch the Perseus area (in the northeast section of the sky) easily. It will help if you are thoroughly familiar with the stars in the area down to about +4.5 magnitude, but this is not essential. When you see a meteor pop, hold the string up with both hands at arms' length and orientate it in direction and length to the meteor's streak. Making a careful mental note of where the streak began and ended, plot it lightly in pencil on your atlas (or a copy of the correct chart).

Some meteors leave a luminous trail or train (as it's called) which can last anywhere from less than a second to several minutes, though the latter is very rare. If you see one, try to estimate how long the train lasts and make a note of it in your records. You may also see a fireball or two. (A fireball is any meteor that's brighter than about magnitude -2.) An estimate of brightness will be harder for one of these because of the lack of a suitable comparison object, but do what you can. If you have a friend along, the other person can record the details (time, brightness, etc.) in a notebook, assigning a sequential number to the record which you put alongside the trail on the star chart.

A different project you can do is to count the number of meteors seen in one hour time intervals, noting, if possible, the brightnesses. This will give you an hourly rate that will change as the night progresses. The observed rate has to be corrected because the radiant is at different altitudes above the horizon as the night goes on (see chart on this page). The result of the correction will be a zenithal hourly rate, which is the world standard. The chart is a general one, intended for observing any meteor shower, which is why it has factors for low elevations. (It won't get dark until the Perseid radiant is at least 15 degrees above the horizon.)

Lastly, you should try to photograph the shower. You can do this either by itself, or while you're doing the other activities. Any camera that has a shutter with B or T settings can be used to photograph meteors. You'll need fast film (Tri-X) and some patience! Set the camera on a tripod or prop it up on blocks so that it's aimed at the radiant, open the aperture as wide as it goes, and focus on infinity. You can probably get away with 1/2 hour exposures unless the sky is bright or the lens is faster than f/2. If you have an equatorially mounted telescope, attach the camera piggyback and take an untrailed photo. Either way makes a nice picture if you're lucky enough to catch a meteor. Remember that your lens won't snag any meteors fainter than about 0 or 1 magnitude. You'll need a wide aperture and small f-ratio to get the faint ones. Astronomers use a Super-Schmidt camera with an aperture of 24 inches and an f-ratio of 0.65! This device gets meteors down to +4 magnitude!

A general hint: Many astronomy enthusiasts find that using a battery operated tape recorder throughout the observing session makes things a bit easier. You can then keep a verbal log to supplement the written one.

Correction for Hourly Rate

Between: (Local Time)		Factor*
8:00 p.m. -	9:00 p.m.	3.3
9:00 p.m. -	10:00 p.m.	2.5
10:00 p.m. -	11:00 p.m.	2.0
11:00 p.m. -	12:00 a.m.	1.7
12:00 a.m. -	1:00 a.m.	1.4
1:00 a.m. -	2:00 a.m.	1.3
2:00 a.m. -	3:00 a.m.	1.1
3:00 a.m. -	4:00 a.m.	**
4:00 a.m. -	4:30 a.m.	**

* Multiply observed hourly rate by this factor to get zenithal hourly rate.

** (No correction necessary after 3:00 a.m.)

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caused by the planet's extremely fast rotation period —less than 10 hours.

On the morning of the 19th, the Galilean satellites will be lined up from west to east in numerical order: I (Io); II (Europa); III (Ganymede), and IV (Callisto). You can also see this on the morning of the 5th, but the elongations aren't as wide.

Saturn

Saturn comes to conjunction with the sun on the 27th, and is thus too close to the sun to be seen well this month.

Uranus

Throughout the month, Uranus remains about one or two degrees west of Alpha Librae, and can be picked up in binoculars at magnitude +5.9. You'll need a telescope with medium to high power to see the disk since the angular diameter is only 3.5 seconds. Look for a pale blob slightly tinged with green.

Neptune

Eighth magnitude Neptune is about two hours of right ascension (30 degrees) east of Uranus. It's just nine degrees east-northeast of Antares. If you center your telescope on Antares and move it five degrees north in declination, you'll be on the declination parallel to Neptune. To find it, move your scope about seven or eight degrees to the east. Neptune should be in the field, but you'll need high powers to make out the 2.5 second diameter disk.

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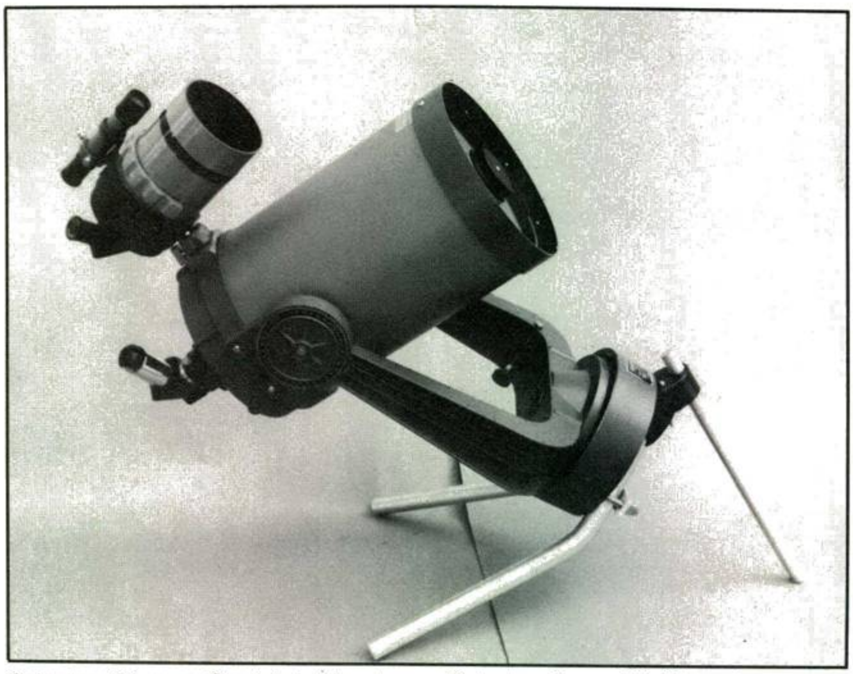

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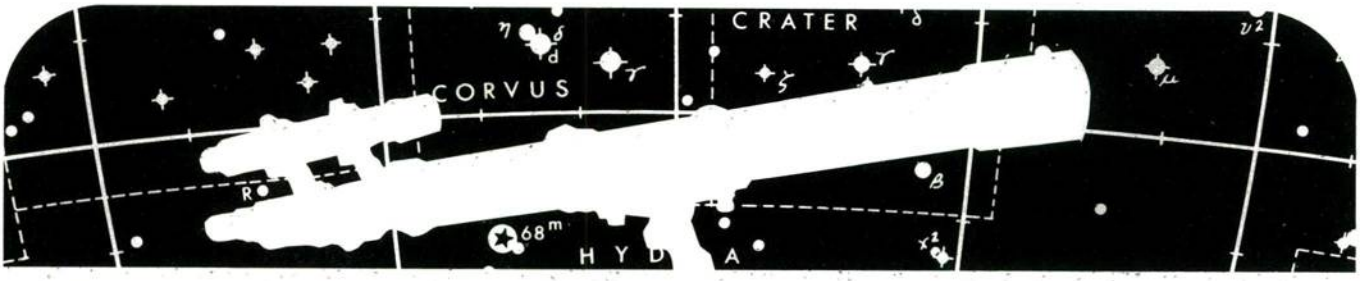


What's Inside Your Telescope? Part 4: Tilted Component and Relay Telescopes

by
Robert E. Cox

In the past few months you've read about telescopes that can be purchased from manufacturers. There are, however, many fine designs that cannot be purchased. The only way you get one of these telescopes is to make it yourself. These special instruments are probably one of the principle reasons the art of telescope making has continued to flourish and expand for more than 50 years in the United States. This month we'll examine a number of these new and exciting optical designs.

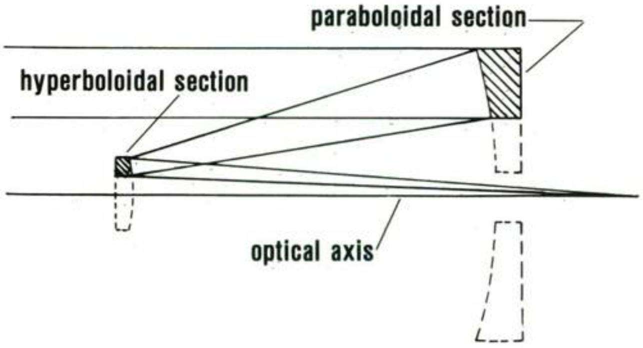
The TCT Telescope

Of all the new designs, the outstanding one is a special visual instrument. It has most of the desirable features of a high quality telescope: Not only can it present an ideal Airy disk and its spurious ring pattern, but because it's an unobstructed system, it yields a high contrast image. Nowadays more and more optical designers are considering this type of system in professional optics. It is often referred to as a *TCT* (Tilted Component Telescope). In a TCT, the mirrors are tipped so that they don't block one another (see drawing 1). The most commonly built TCT in the U.S. and foreign countries has been the Kutter Schiefspiegler (German: oblique reflector), designed by Anton Kutter.

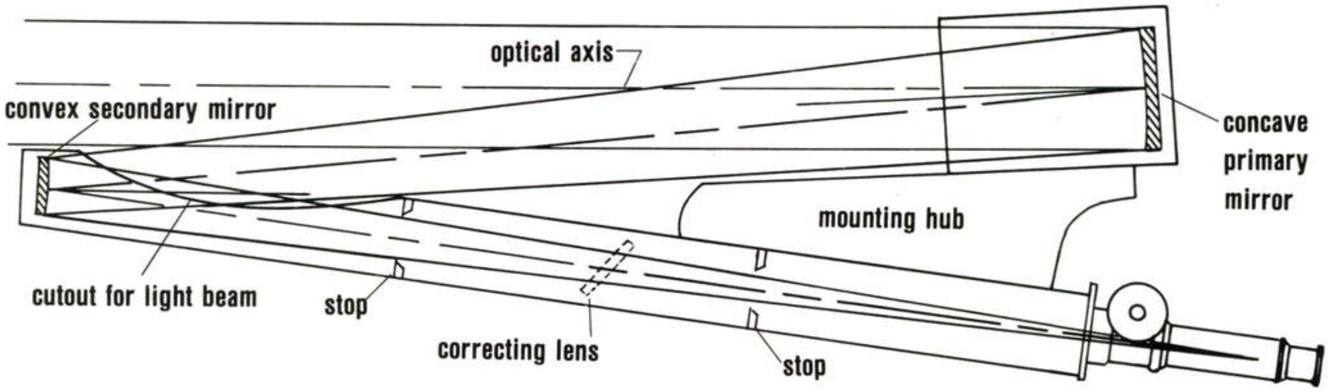
Although it looks like the design could be a special form of off-axis mirror system cut out of a Cassegrainian type telescope, it isn't. Its mirrors are simply tilted around their center.

Dr. Richard A. Buchroeder of the Optical Sciences Center in Tucson, Ariz., has defined several different classes of unobstructed reflectors. The eccentric pupil type (shown in drawing 2a) is simply cut out of a complete Cassegrain telescope. Note the axis line of the complete optical system — of which the partial mirrors are a decentered part — does not pass through the mirrors. The mirror figures are decentered sections of aspheric surfaces, and are very difficult to make. The TCT

Drawing 2a: OFF-AXIS CASSEGRAIN

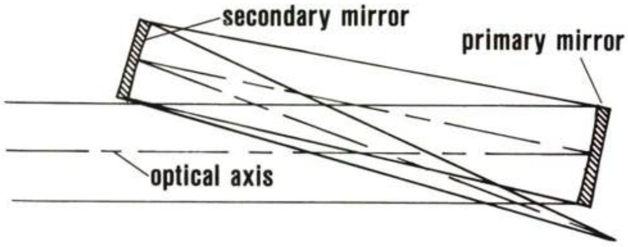


Drawing 1: SCHIEFSPIEGLER


optical axis
convex secondary mirror
concave primary mirror
mounting hub
cutout for light beam
stop
correcting lens
stop

(drawing 2b) has an optical axis that passes through the center of each mirror through the system to the final focus. The mirror figures, when they are nonspherical, are centered on the mirror, making fabrication simpler.

Drawing 2b: TWO MIRROR YOLO T.C.T.

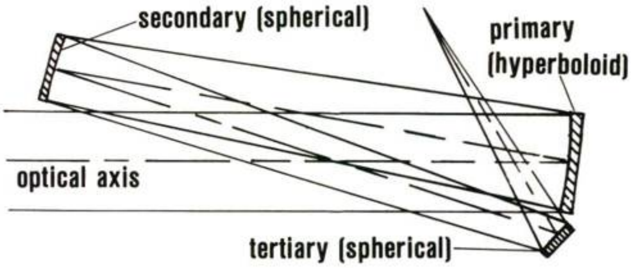

secondary mirror
primary mirror
optical axis

Although in sizes up to 4-1/4 inches aperture, a Schiefspiegler uses all spherical mirrors, in larger sizes it's necessary to make the primary mirror aspheric. The primary has a figure with about 55 percent correction of a paraboloid of the same Newtonian mirror size and focal length. Since these mirrors have long focal lengths, the correction is slight and easy to apply. In addition, further correction is needed: It can be obtained by making the smaller convex mirror cylindrical in shape — two different radii at right angles to each other — or by placing a weak tilted plano-convex lens in the light beam from the secondary mirror (shown by the dashed lens in drawing 1).

Since final focal length of Schiefspieglers is quite long — f/20 to f/26 — they are used mostly for lunar, planetary and double star work. The largest size instruments are in Europe where there are several 12 inch telescopes. A number of 10 inch Schiefspieglers have been built in the U.S.

Another form of TCT, developed by Dr. Arthur S. Leonard, uses two concave mirrors tilted to obtain the final correction. His first disclosure of the system was in 1970 at the Annual Convention of the Western Amateur Astronomers. Leonard described his Yolo system (he names his designs for counties in California in which he resides) and presented several other designs, some of which used more than two mirrors. In drawing 3 the light path through his Solano telescope is shown. Note that the tertiary (third) mirror has a convex surface while the other two are concave. The primary has a hyperbolic surface while the remaining two are spherical. Three mirror Schiefspiegler designs have also been developed by Kutter and Buchroeder.

Drawing 3: SOLANO T.C.T.

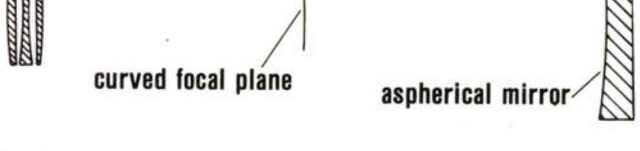

secondary (spherical)
primary (hyperboloid)
optical axis
tertiary (spherical)

All Spherical Catadioptric Telescopes

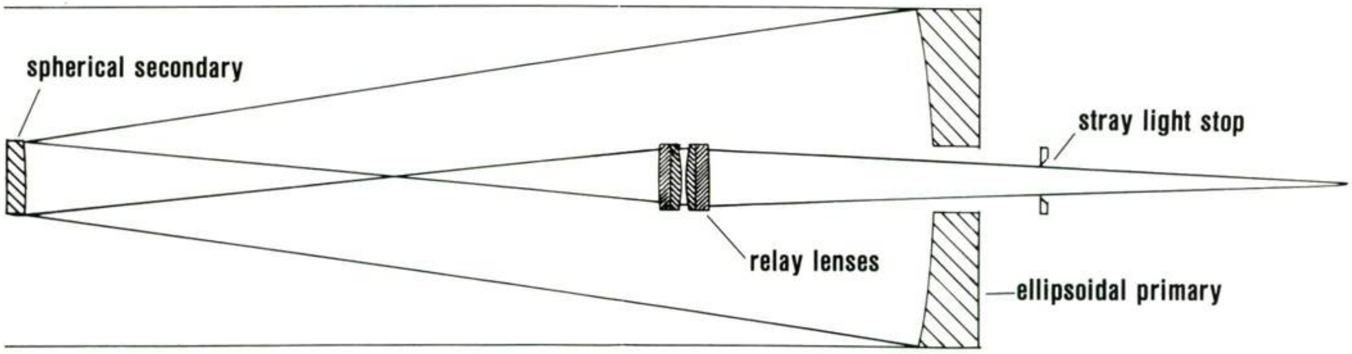
Large Aperture Designs — Nonspherical mirrors are far more difficult and time consuming to make than spherical optics. Today it's possible to design some very fine telescopes using only spherical surfaces on the various elements.

James L. Houghton filed a patent in March 1942 for an instrument that had the characteristics of the Schmidt camera; instead of the strongly deformed correcting plate, however, it used a series of all spherical glass lenses. These introduce spherical aberration that cancels that of the primary mirror. A camera (see drawing 4) designed by Buchroeder goes a step further. All the curved surfaces have the same radius — the other two are flat — and all use the same glass type. The

Drawing 4: HOUGHTON CAMERA


spherical lenses
curved focal plane
aspherical mirror

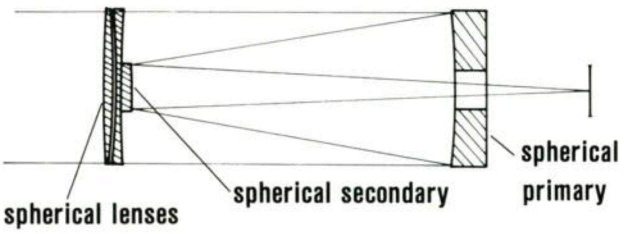
Drawing 8: DALL-KIRKHAM RELAY TELESCOPE


spherical secondary
stray light stop
relay lenses
ellipsoidal primary

images on the f/3 camera should approach a Schmidt camera's quality on the final curved image plane.

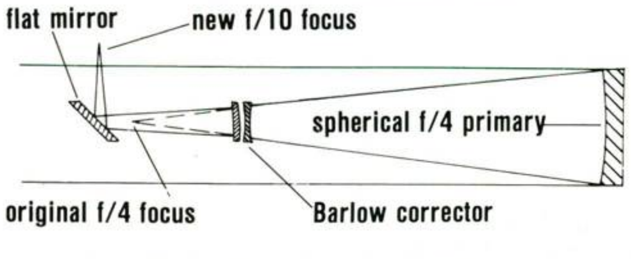
It's also possible to extend the Houghton principle to a Cassegrain type by adding a convex secondary mirror. This Cassegrainian telescope uses all spherical surfaces on the optics. The telescope shown in drawing 5 was designed by Robert D. Sigler of Ann Arbor, Mich. Sigler is now constructing a 10 inch instrument for his own use: The completed instrument will be f/9.44, with a two degree diameter diffraction limited field! The work is expected to be completed — and the telescope tested and evaluated — by early fall 1978. Construction specifications will be released for hobbyist use, though commercial rights will be restricted.

Drawing 5: SIGLER HOUGHTON CASSEGRAIN


spherical lenses
spherical secondary
spherical primary

Small Correcting Lens Designs — Because large full aperture pieces of optical glass are expensive, telescope makers try to avoid them. Today there are new designs which not only use all spherical optics, but also lenses that are small in diameter.

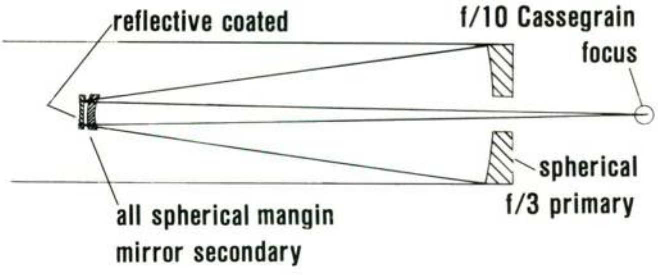
Drawing 6: JONES CATADIOPTRIC


flat mirror
new f/10 focus
spherical f/4 primary
original f/4 focus
Barlow corrector

Robert T. Jones designed a Newtonian form of telescope in 1957 which consisted of an f/4 spherical primary mirror and a "correcting" Barlow lens. The final f/10 instrument has excellent definition across the field. The chromatic aberration introduced by the lenses was less than half that of a similar size f/10 refractor. The Barlow, while extending the primary focal length, induces enough spherical aberration to cancel that of the primary mirror. A 10 inch aperture telescope of this design has been built, and reportedly gives outstanding performance. One feature of the system is its short tube — any observer appreciates an f/10 telescope in an f/4 tube!

The next obvious step is to alter the curves of the lens, coat the rear surface of the Barlow to make a *mangin mirror* (a refracting element which has a reflecting surface applied to the back), and alter the design to that of a Cassegrainian telescope. In fact a German, H. Acht, did file a patent for a photographic lens of this nature in February 1934. Then, in 1968, a Russian optical journal published a description of an astronomical version of a similar lens designed by P.P. Argunov. His all spherical catadioptric design had a large spherical primary mirror and two small spherical lenses, with one surface coated to make the assembly a mangin mirror (see drawing 7). According to the article, a 16.75 inch aperture system had been built and was in operation at the Crimea Astrophysical Observatory. Several modern American designs are now in the prototype stage. With ordinary glass types (BSC-2 and DF-2), the chromatic aberration in these instruments is considerably less than an equivalent full aperture refractor. However, if special glass types are used in the design, it appears

Drawing 7: ARGUNOV CATADIOPTRIC CASSEGRAIN

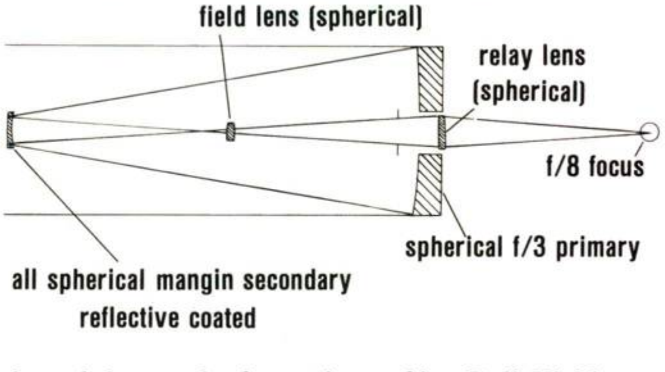

reflective coated
f/10 Cassegrain focus
spherical f/3 primary
all spherical mangin mirror secondary

possible to design aprochromatic instruments with almost no chromatic aberration at all.

Like their all reflective counterparts, mangin mirror secondary telescopes require careful baffling or stray light will cause a fogged field of view. One way to eliminate the stray light problem is to design the telescope so that the image comes to focus between the secondary mirror and the primary. This image can be relayed with lenses to a final focus. A diaphragm placed at the point where the relay lens images the secondary mirror can then remove all stray light without resorting to long baffle tubes. Horace E. Dall of England built a pocket telescope based on this principle. An eight inch aperture scaled up version (made by Robert Cox!) — although limited by poor war surplus relay lenses — still proved to be a fine low power astronomical and terrestrial instrument. Since the relay gives an erect final image, such designs can be used for terrestrial viewing. The telescope (see drawing 8) was a Dall-Kirkham design, with an ellipsoidal primary and spherical secondary mirror. Relay design telescopes can have faster optical systems than those with regular Cassegrain optics. Using an f/3 primary, a final focal ratio of f/8 is readily obtainable.

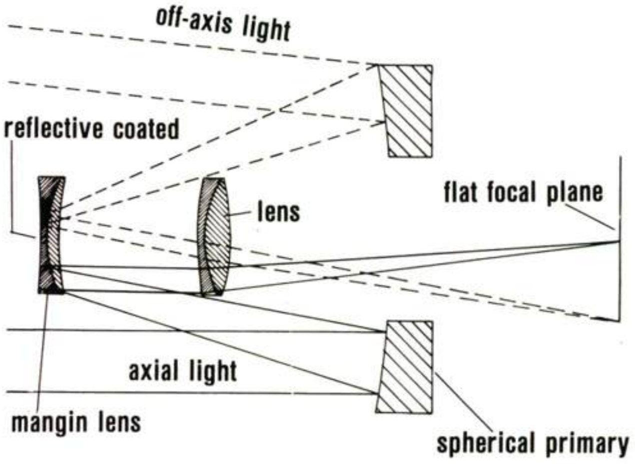
While a student, Buchroeder designed an astronomical telescope with a relay lens and followed it with an improved and simplified system of fewer lenses. In 1969 he designed a simple form of relay telescope (having limited performance compared to a classical Cassegrainian) that utilized an f/3 spherical primary mirror and three simple single element lenses. Drawing 9 shows the optical arrangement: One lens is a mangin secondary, one is a field lens, and the last is the relay lens. Although all lenses use the same type glass, the instrument is free of chromatic aberration and has Dall-Kirkham performance at f/8 over a 30 minute of arc field. A prototype is now being tested and evaluated in the St. Louis, Mo. area. A similar design by Sigler features a further simplification: The back surface for the mangin secondary is flat, making fabrication simpler. The largest simple relay telescope is one designed and built by Donald Dilworth; it has a 16 inch aperture and operates at f/7.

Drawing 9: BUCHROEDER RELAY TELESCOPE



An unusual photographic telescope using a small lens, large mirror design is a catadioptric suggested by A. Wilkinson of England. It has the capability of giving Schmidt camera quality performance with a flat focal plane that is readily accessible. In drawing 10, the solid lines represent light from an axial object, and the dashed lines an object at the edge of a 4-1/2 degree field (total field nine degrees) on 2-1/4 inch square film. The focal length of the f/4.5 system is 500mm. Two prototype systems are now being tested in England.

Drawing 10: WILKINSON WIDE FIELD CATADIOPTRIC



Unfortunately, few telescope makers have attempted lens making. Except for a few Schmidt and Maksutov corrector elements made by advanced workers, lensmaking has yet to be discovered by the majority of telescope makers — although telescopes using lenses offer tremendous advantages. Perhaps we'll someday see the lenses made commercially and sold as a package; you could then make the large mirror needed to complete the design. It would be almost the same as buying an eyepiece for your telescope! Hopefully, the cost for at least some of the designs would be similar to that of a high quality eyepiece.

Commercial rights to the instruments described here are restricted. However, when prototype testing and evaluation is completed, we hope that either complete telescopes or correcting elements will become available to telescope makers and observers.

There are no specifications given for the designs in this article because it's an introduction to these new ideas. We hope all of our readers — from those just beginning to those more experienced — will benefit.

Specifications and, in some cases, detailed fabrication information will appear in a new magazine called TELESCOPE MAKING, to be published by AstroMedia Corp. on a quarterly basis starting in October 1978. TELESCOPE MAKING will carry features at all levels in the hobby of telescope making and related fields.

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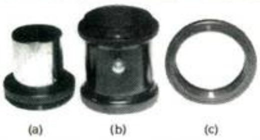

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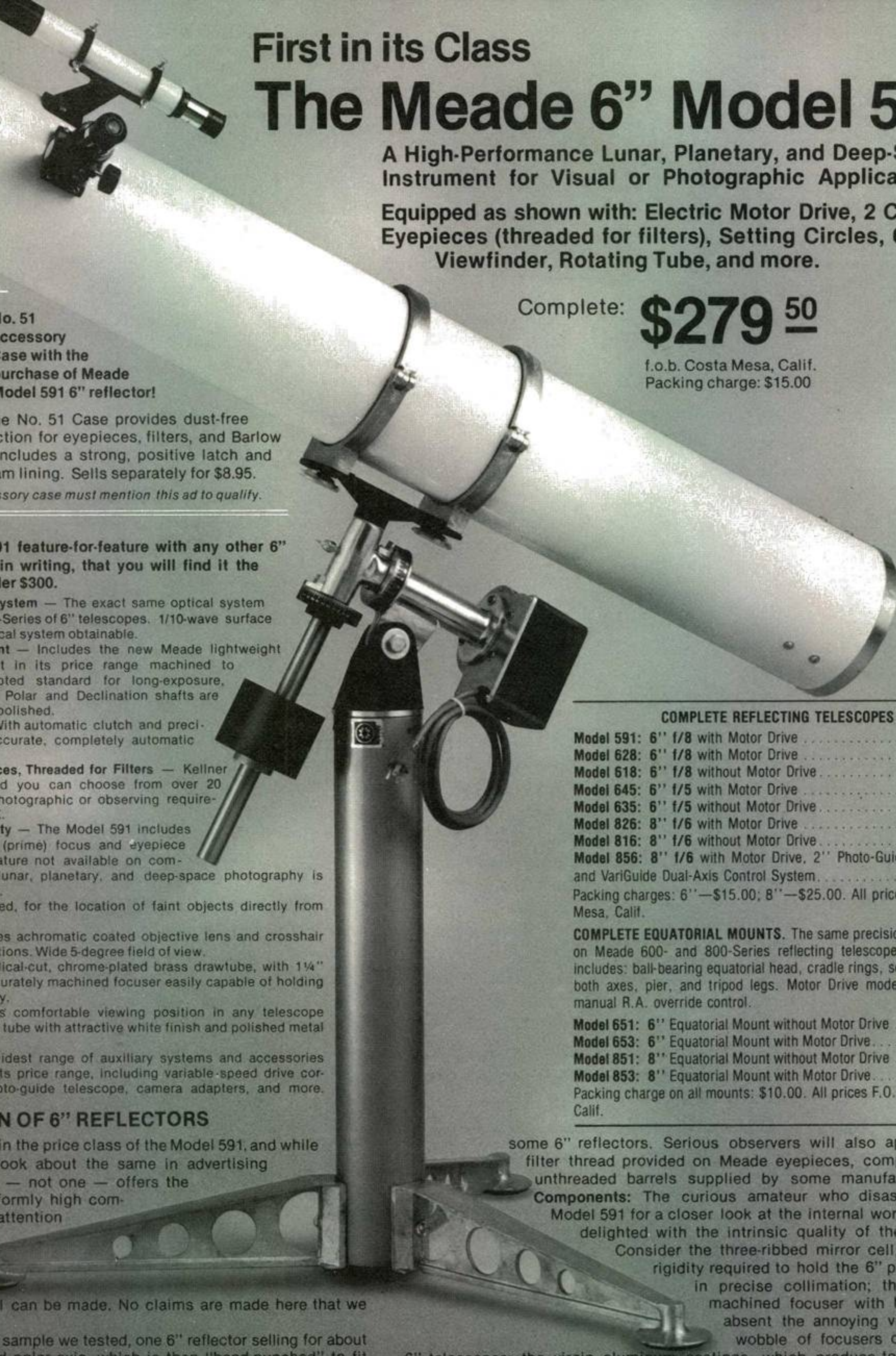

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A FRANK COMPARISON OF 6" REFLECTORS

There are other 6" telescopes in the price class of the Model 591, and while most 6" reflectors tend to look about the same in advertising photos, no competing model — not one — offers the precision machining, the uniformly high component quality, or the careful attention to detail of this Meade 6" telescope. The following discussion is as honest and straightforward a comparison as we feel can be made. No claims are made here that we cannot fully support.

Equatorial Mounts: Based on a sample we tested, one 6" reflector selling for about $250 uses a roughly-machined polar axis, which is then "hand-punched" to fit the polar shaft — a crude practice on what is claimed to be a "fine instrument." The declination shaft of the same telescope wobbles in its casting unless literally locked in place. Meade equatorial mounts are fully machined on $10,000 lathes to tolerances within .001", and are capable of the fine guiding absolutely essential for serious observing and quality astrophotography.

Eyepieces: The Kellner eyepieces supplied with the Model 591 yield apparent fields of view significantly wider than the Ramsden eyepieces supplied with some 6" reflectors. Serious observers will also appreciate the filter thread provided on Meade eyepieces, compared to the unthreaded barrels supplied by some manufacturers.

Components: The curious amateur who disassembles his Model 591 for a closer look at the internal workings will be delighted with the intrinsic quality of the instrument. Consider the three-ribbed mirror cell, with all the rigidity required to hold the 6" primary mirror in precise collimation; the beautifully machined focuser with helical gears, absent the annoying vibrations and wobble of focusers on competing 6" telescopes; the virgin aluminum castings, which produce tooled surfaces almost as smooth as glass.

In sum, if we seem to be proud of our 6" telescope, it's because we know the Model 591 is the best in its class by a wide, wide margin.

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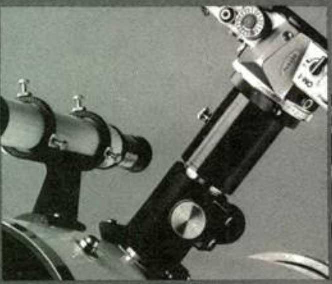

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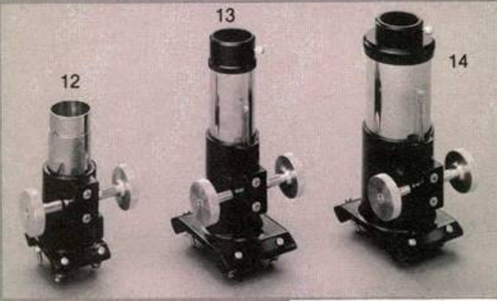

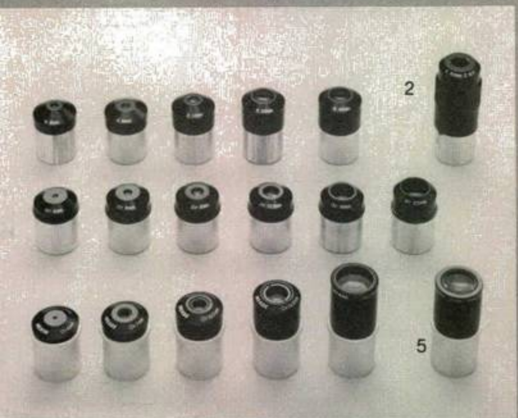

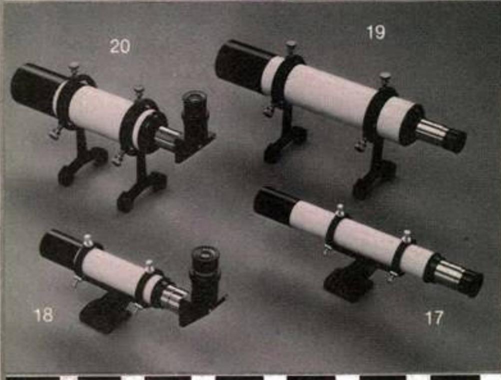

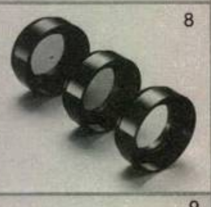

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GAZER'S GAZETTE

Naked Eye Astronomy

Part 2

by

Fred Schaaf

Anyone who has seen the starry sky on a dark, transparent country night has surely felt the deepest satisfaction with that overwhelmingly wonderful and direct perception of the universe. Yet, strangely, even with that peerless sight as an inspiration, naked eye astronomy has been badly neglected. It seems that nowadays a great number of people subscribe to the theory that "whatever the eye can see, the telescope can see better".

That theory just doesn't hold up. Among the obvious exceptions are the spectacular displays of a meteor shower or an aurora. More importantly, this idea misses the whole point: Naked eye observing is not *poorer* than the telescopic view — it's simply *different*. Naked eye observing complements and even improves the pleasures of telescopic viewing. Practicing with your unaided vision not only makes you a more diligent and perceptive observer — it also enables you to gain a useful (and delightful!) familiarity with the sky. Then, when you have to hunt for that 10th magnitude Messier object or some new seventh magnitude comet, you're ready.

Faint Stars, Asterisms, Star Clusters

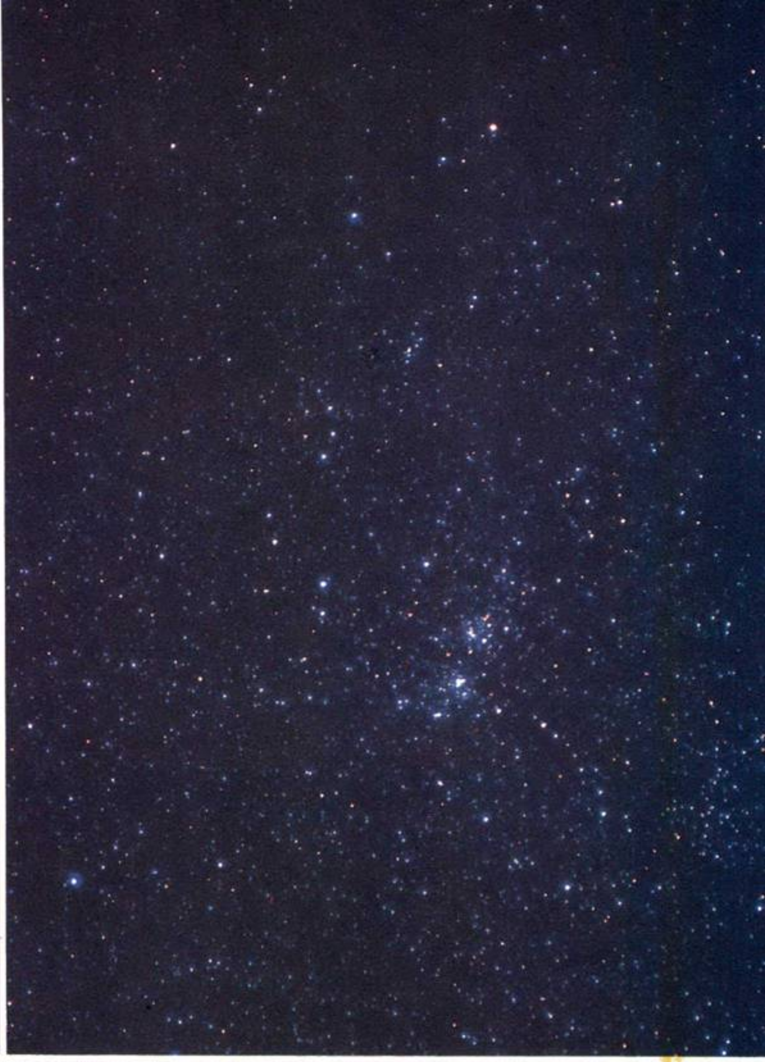
When you do find yourself in fairly dark, haze-free skies, you'll quickly discover how conservative the often quoted "limits of naked eye visibility" really are. If you use a chart (such as the one on page 45), you can find your personal magnitude limit on any given night. To see the faintest objects, try fixing them in your memory in relation to brighter stars which together form simple geometric figures — usually lines or triangles. Cupping your hands around your eyes or peering through an oatmeal box "telescope" may be helpful for your concentration. Another trick is *averted vision*, essential for stars near your limit. Rather than look right at a faint star, look a bit to the side; suddenly you'll see it. As soon as you glance back, you'll lose it again. Averted vision works because the most light sensitive areas in your eyes are not dead center.

Looking for faint stars can be a painstaking challenge, but an activity of a different character is finding asterisms of fifth, fourth, or brighter magnitude stars. In the course of your detailed observation, you'll not only become fascinated with graceful or peculiar groupings you never noticed before, but you'll also begin to find wide double stars, or interesting areas rich or devoid of stars, and fuzzy spots that turn out to be star clusters.

The number of open clusters easily visible to the naked eye is seldom mentioned. Even if you exclude the most famous naked eye clusters — the Hyades, Pleiades, Beehive, Coma, and Double Cluster in Perseus — and count only those open clusters of sixth magnitude or brighter that are north of -35 degrees declination (and those -40 degrees, and brighter than fifth magnitude), you'll still end up with a list of no less than 25 objects! Among those are famous objects like big M-35, an easy sight under any reasonably good conditions. But there are also many surprises including the 5.1 magnitude open cluster IC-1396 in Cepheus, and IC-4756, a giant cluster 70 minutes of arc across in Serpens. In the autumn, while scanning the Milky Way, you might notice a fuzzy looking "star" off to one side: NGC-1502, a notable cluster, in Camelopardalis of all places!

Not far east of Betelgeuse is a renowned object which has seldom been suggested as a naked eye

Surprisingly, there is quite a selection of subjects for you to choose from when observing with only your eyes. Top left: These two open clusters — the Hyades (V-shaped) and the Pleiades (dipper shaped), are favorites among winter observers. This photograph was taken using High Speed Ektachrome (ASA 400) exposed for 25 seconds, with a 55mm lens at f/1.8. Photograph by Bill Miles. Top right: One of the more famous naked eye clusters is the Double Cluster in Perseus. This is an eight minute exposure on GAF 200 film using a 200mm lens at f/3.5. Photograph by Dennis McDowell. Bottom left: The Andromeda galaxy is shown here in this 8-1/2 minute exposure on GAF 500 film with a 400mm lens at f/6.3. Photograph by Conrad Kussner. Bottom right: This shot of M-13, a globular cluster, is a five minute exposure on GAF 500 film using an eight inch f/5 reflector at prime focus. Photograph by Bob Kimmel.



sight. NGC-2244 is a naked eye cluster surrounded by the famous Rosette nebula. In dark skies, a rich field telescope will show dim traces of the rich nebulosity which is so beautiful in photographs. While the cluster itself is lovely in a telescope, it can easily be found, seen and pointed out to others *without* optical aid!

Many spectacular open clusters are a little too faint to pass our strict sixth magnitude requirement. M-11 in Scutum is an excellent example, for it can be seen easily with the naked eye! Also not on our list are rich groupings that are not always considered to be true clusters, and consequently get overlooked in ordinary compilations of selected sky objects. An example is the very large bright grouping just below Alpha Persei (Mirfak). The combined brightness of this attractive bunch of sparklers is about second magnitude; on a clear night they are a fascinating sight with eyes alone, and a breathtaking one in binoculars or a wide field telescope.

For northern observers, only two globular clusters are brighter than sixth magnitude — but seven more are brighter than 6.5! M-13, high in the sky from most of the United States, is an easy sight! All in all, a total of about 50 clusters, open and globular, lie within the range of naked eye observers in very dark skies.

Milky Way

Hardly anything can match the dreamy grandeur of the Milky Way on a clear, moonless summer night away from city lights. But the winter part of our galaxy is interesting, too. Any stretch of the Milky Way is an intriguing study in irregular flow. You'll spend many nights if you try to sketch its different intensities and positional relations to the bright and faint stars which it runs around and past. Especially in the summer Milky Way, you'll notice many different levels of brightness. The large Cygnus, Sagittarius and Scutum starclouds stand out spectacularly, but localized areas such as magnificent M-24 are even brighter.

When you explore the great heavenly river of light, you'll not only notice objects like the Lagoon nebula (M-8) with your naked eye, but find attractive areas which you can then investigate with binoculars or a telescope. Many of these regions aren't mentioned in books, so only your own celestial touring can bring their discovery to you.

How do various atmospheric conditions affect the appearance of the Milky Way? In many subtle ways, each night presents a different view — as if the infinite richness of our galaxy needed any more variety! Interestingly, haze seems to obscure the Milky Way less than it does the brighter stars.

The great spiral galaxy in Andromeda is another easy naked eye sight, and is also interestingly affected by less-than-obvious atmospheric changes. How much of its length and breadth can you detect with the unaided eye? On any given night, it'll probably be more than with anything but an RFT. On an excellent night, try to spot even more distant M-33 in Triangulum with the naked eye.

Bright Stars and Planets in Daytime

There are not many recorded instances of stars or planets — other than Venus — being seen with the naked eye while the sun was still above the horizon. The best collection of such sightings in the 19th century (a short list) is probably Webb's classic **Celestial Objects for Common Telescopes**. In his wonderous book **The Nature of Light and Color in the Open Air**, Prof. Minnaert described hundreds of observational possibilities for the naked eye — some of them astronomical — and claimed that Venus could sometimes be followed throughout the day, Jupiter could be seen near sunrise or sunset (but was very difficult when the sun was at more than 10 degrees elevation), and that Mars was rarely visible. [The Webb and Minnaert books are both available as Dover reprints.]

Sightings of Jupiter can be made with relative ease. Indeed, there's little doubt that you could follow the planet through midday. You don't need abnormally good eyesight — just regular 20-20 vision in bright daylight.

Most daytime Jupiter observations require preparation. Good binoculars are very helpful since they can be used at standing or sitting eye level. After finding the target star or planet, they can be quickly removed so that the precise position of the object is kept in view. The one secret to seeing planets or stars in a bright sky is knowing exactly where to look.

Test this method first with Venus since it's much easier to find. Follow it into the sky after sunrise (when it's a morning star), or find it with some good estimating and binoculars (or RFT), or use a telescope with setting circles to dial its position.Then line up the known position of Venus with some foreground object, and look. You may have to hunt awhile — possibly for as long as 10 or 15 minutes the first time you try — but suddenly your eyes will stray to Venus. You'll be surprised at how plain it appears — a small, intensely bright point. It's an amazing sight to see in the same sky as the sun around which it orbits!

Venus should be visible in the middle of any clear day as long as the sun is not too close. Though Venus can even be seen in the daytime through moderately thick clouds, haze can make it much less plain. Avoid haze in your search for any of the fainter objects. The ideal procedure might be to attach a small sighting ring parallel to your telescope with which to follow the target object; for the naked eye, the object would then be centered inside the sighting ring. This would be an excellent project for members of an astronomy club.

Resolution

Some books suggest that in steady air, the

Naked Eye Clusters

Open Clusters

Object	R.A. (1950)	Dec.	Diameter	Magnitude	Number of Stars	Constellation
NGC-1029 (M-34)	$2^{h}39^{m}$	+42°34'	18'	5.5	80	Perseus
NGC-1502	$4^{h}03^{m}$	+62°11'	7'	5.3	15	Camelopardalis
NGC-1746	$5^{h}01^{h}$	+23°44'	45'	6.0	60	Taurus
NGC-2168 (M-35)	$6^{h}06^{m}$	+24°20'	40'	5.3	120	Gemini
NGC-2244	$6^{h}30^{m}$	+ 4°54'	40'	5*	16	Monoceros
NGC-2264	$6^{h}38^{m}$	+ 9°56'	30'	4.7	20	Monoceros
NGC-2287 (M-41)	$6^{h}45^{m}$	−20°42'	30'	5.0	50	Canis Major
NGC-2301	$6^{h}49^{m}$	+ 0°31'	15'	5.8	60	Monoceros
NGC-2353	$7^{h}12^{m}$	−10°12'	20'	5.3	25	Monoceros
NGC-2422 (M-47)	$7^{h}34^{m}$	−14°22'	25'	4.5	50	Puppis
NGC-2437 (M-46)	$7^{h}49^{m}$	−14°42'	24	6.0	150	Puppis
NGC-2447 (M-93)	$7^{h}42^{m}$	−23°45'	25	6.0	60	Puppis
NGC-2451	$7^{h}44^{m}$	−37°51'	45	3.6	50	Puppis
NGC-2546	$8^{h}11^{m}$	−37°29'	40	4.6	50	Puppis
NGC-2548 (M-48)	$8^{h}11^{m}$	− 5°38'	30	5.3	80	Hydra
NGC-6383	$17^{h}31^{m}$	−32°33'	6	5.5	12	Scorpius
NGC-6405 (M-6)	$17^{h}37^{m}$	−32°11'	25	5.3	50	Scorpius
IC-4665	$17^{h}44^{m}$	+ 5°44'	60	5.9	13	Ophiuchus
NGC-6475 (M-7)	$17^{h}51^{m}$	−34°48'	60	3.2	50	Scorpius
NGC-6603 (M-24)	$18^{h}16^{m}$	−18°27'	4	4.6	50	Sagittarius
NGC-6633	$18^{h}25^{m}$	+ 6°32'	20	4.9	65	Ophiuchus
IC-4756	$18^{h}37^{m}$	+ 5°26'	70	5.1	80	Serpens
NGC-6871	$20^{h}04^{m}$	+35°38'	37	5.6	60	Cygnus
NGC-7092 (M-39)	$21^{h}30^{m}$	+48°13'	30	5.2	25	Cygnus
IC-1396	$21^{h}38^{m}$	+57°16'	50'	5.1	30	Cepheus

Globular Clusters

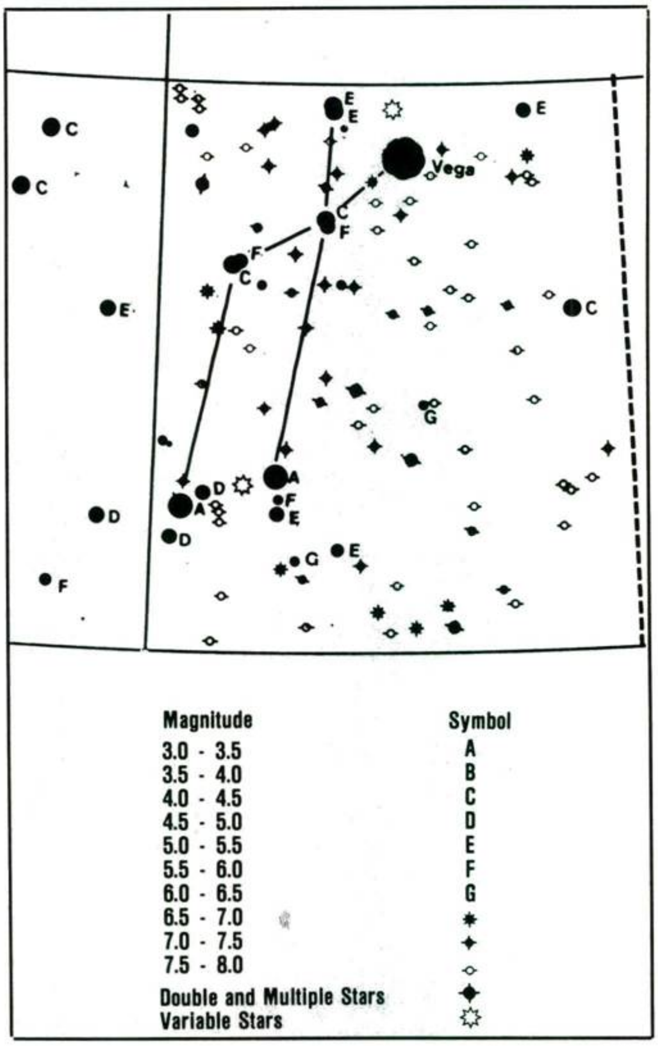
Object	R.A. (1950)	Dec.	Diameter	Magnitude	Number of Stars	Constellation
NGC-5272 (M-3)	$13^{h}40^{m}$	+28°38'	19'	6.4	—	Canes Venatici
NGC-5904 (M-5)	$15^{h}16^{m}$	+02°16'	20'	6.2	—	Serpens
NGC-6121 (M-4)	$16^{h}21^{m}$	−26°24'	23'	6.4	—	Scorpio
NGC-6205 (M-13)	$16^{h}40^{m}$	+36°33'	23'	5.7	—	Hercules
NGC-6341 (M-92)	$17^{h}16^{m}$	+43°12'	12'	6.1	—	Hercules
NGC-6656 (M-22)	$18^{h}33^{m}$	−23°58'	17'	5.9	—	Sagittarius
NGC-6809 (M-55)	$19^{h}37^{m}$	−31°03'	15'	6.0	—	Sagittarius
NGC-7078 (M-15)	$21^{h}28^{m}$	+11°57'	12'	6.0	—	Pegasus
NGC-7089 (M-2)	$21^{h}31^{m}$	−01°03'	12'	6.3	—	Aquarius

average naked eye can just barely split Epsilon Lyrae — a separation of 208 seconds of arc. But even the average observer is probably capable of doing better. Epsilon Lyrae just happens to be one of the few wide pairs that are not only bright, but also almost equally bright (the ideal situation).

In 1976, Mars occulted Epsilon Geminorum. At least one naked eye observer was able to separate them when they were 153 seconds of arc apart (he may have been able to achieve better if he had tried when they were closer). In this case, the planet was two magnitudes brighter than the star. What could be split by an average or keen eyed observer with two equally bright objects of suitable magnitude?

In his **Color Star Atlas**, noted astronomy writer Patrick Moore said the well-known double Nu Draconis (also named Kuma) can be split by a person with superb eyesight. The two components of Nu Draconis are each 4.6 magnitude, but their separation is only 62 seconds.

Nu Draconis may well seem to be the ultimate test of naked eye resolution, but two other semilegendary feats should be mentioned: seeing the crescent of Venus and the elongated shape of Saturn. Venus sometimes exceeds 60 seconds of arc across when it is a thin crescent, but then it is



This chart is intended to help you determine what your personal magnitude limits really are. It doesn't include magnitudes greater than 3.0 because Lyra doesn't contain any — with the obvious exception of Vega. Try fixing the configurations of the brighter objects in your mind. When you know where they are, it may help you to detect the fainter ones.

usually quite close to the sun. Perhaps the best situation would be to have Venus at only 50 seconds, but at a much greater elongation from the sun and high in the daytime sky. (Although definitely a difficult task, even under these conditions, it certainly seems well within the realm of possibility.)

To detect the shape of Saturn unaided, however, would seem to be virtually impossible. But at what magnification can a person first detect the rings? It would be interesting to try observing Venus and Saturn under favorable conditions, with a two or three power finder or opera glasses.

A final task of resolving ability that anyone can do is studying features on the moon with the naked eye. Try it by day, night and twilight, at different phases. You'll be amazed at the small detail you can distinguish!

Pleiades, Jupiter's Moons

Finally, take a look at two more famous possibilities for naked eye astronomy. The first is counting the stars of the loveliest of clusters, the Pleiades.

There are nine Pleiads brighter than sixth magnitude, and about 25 brighter than seventh magnitude, but they are gathered into a small, dazzling area, so resolving ability becomes important. To get the best results, you should know exactly where to look for the fainter stars. On good country nights at least eight or nine Pleiads should be visible. On superb nights the average determined observer may see 12 or more. The record for Pleiads is 18, by a famous present day observer.

The most unusual accomplishment for a naked eye observer is, very probably, the sighting of Jupiter's moons, Callisto and Ganymede. Choose a night when Callisto is quite near its greatest western or eastern elongation. Study Jupiter carefully for any sign of that faint satellite nearby. Perhaps if you stand behind a tall building so that Jupiter is just cut off, you'll see the faint residual flicker of its moon. It's important to pick a slightly hazy night, when the "rays" of Jupiter appear less extended. Ganymede may actually be easier when it's in the proper position — almost exactly at greatest elongation.

Give It a Try

There are dozens of other targets for naked eye astronomy. The mysterious zodiacal light and its fainter extensions, the Gegenschein and zodiacal band, are not exceptionally difficult to see in dark skies — even when it's not quite the best time of year for them. A longtime observer has said that from the Pocono Mountains of northeast Pennsylvania, the Gegenschein is sometimes "spectacular"!

And what about variable stars? With the naked eye, it's easy and enjoyable to watch short period performers like Algol and Beta Lyrae, bright long periods such as Mira and Chi Cygni, and irregulars like brilliant Betelgeuse. You can also check for the very slight — but real — possibility of a new flare-up by a wilder object: Is the pattern of Corona Borealis normal, or has T (the "blaze star"), the famous recurrent nova, flamed up to second magnitude again?

Search for the youngest moon you can see in twilight — the crescent as soon after new moon as possible — and the youngest moon in broad daylight. You can look for common halos, rainbows and stranger phenomena such as moon pillars. Look for the green ray at sunset and the gorgeous play of colors when Sirius and other bright stars are twinkling low in the sky. Can you see the shadow of your hand cast on a white surface by Venus? See if you can determine the color of stars with the naked eye — even ones as faint as second magnitude — and then double check with binoculars or telescope.

The list goes on and on, and what becomes ever more clear is the great ability of the human eye. Find the best skies you can and hunt for whichever of these sights appeal to you. Even for the more difficult observations, the only indispensable ingredient is your own enthusiasm.

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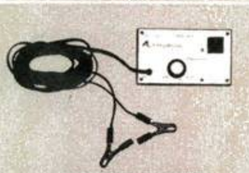

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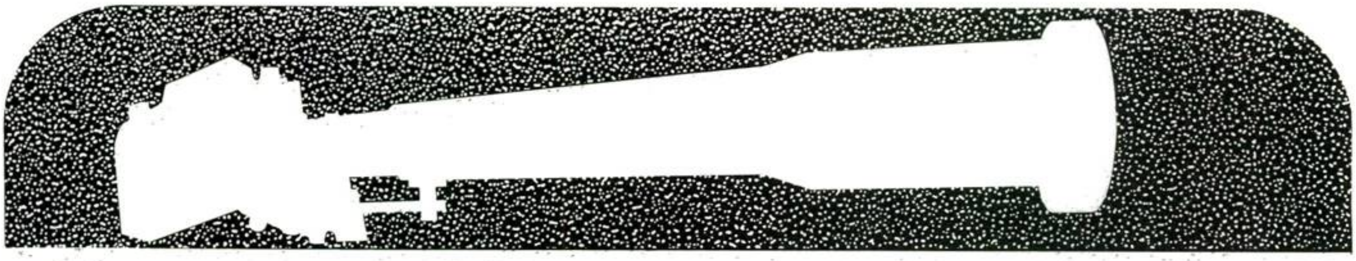
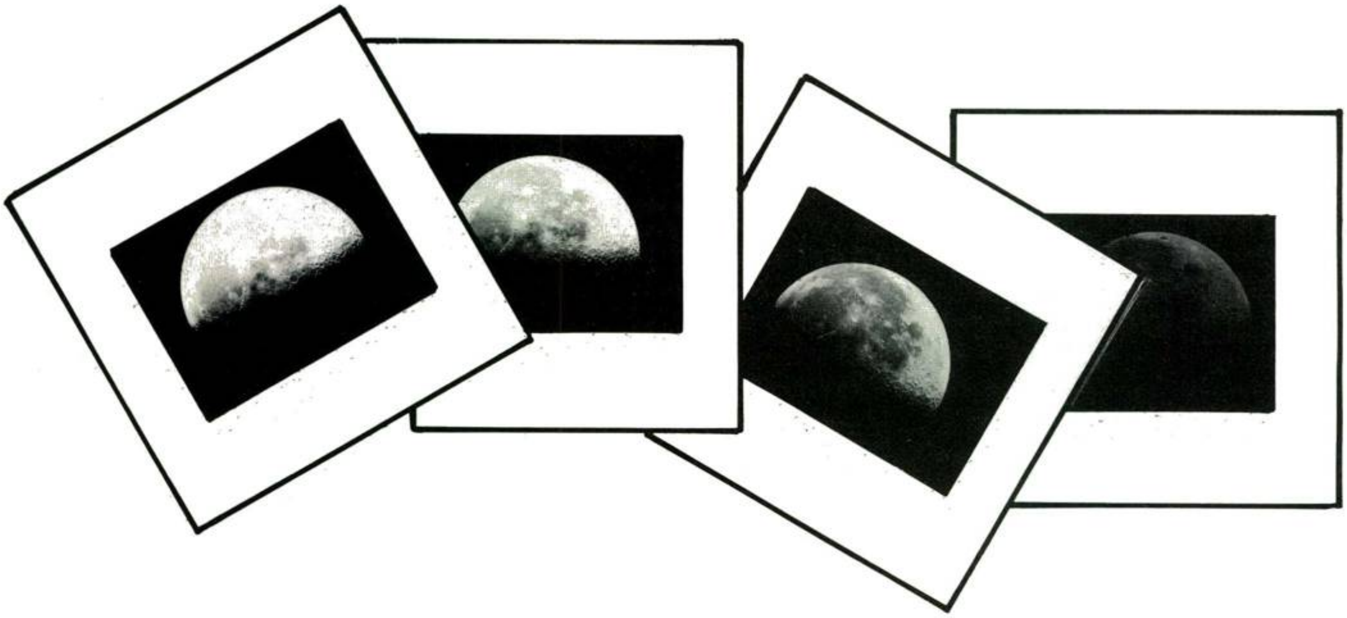


PHOTOGRAPHY IN ASTRONOMY

Exposure in Astrophotography

by

Richard Berry



The question that faces every astrophotographer each time the shutter button is pressed is, "How long must I expose?" Exposure is crucial: Too much light striking the film results in a negative too dark to use (or a slide too light), and too little fails to form an image at all. Between the extremes lies a broad range of useful exposures. But the best results — an image neither too light nor too dark — depend on precise exposure. Just what is the "right" exposure in astrophotography?

Of course, the exposure that's "right" isn't necessarily right for every purpose. Astrophotography is a specialized type of photography — the photography of bright objects on a dark background, rugged landscapes, and the photography of clouds on other planets. Your goal is to expose such that the significant detail in the picture (or negative) falls in the middle of the range of densities the slide (or negative) can produce.

What do we mean by significant detail? Let's examine a specific instance: Imagine that you're taking a picture of the constellation Cygnus (the swan) centered on the star Deneb, using an ordinary camera attached to your telescope for piggyback tracking. What, you ask, is the correct exposure?

There are at least three answers. If you want to show the bright stars and constellations only, then your exposure is short — 10 seconds or thereabouts. If you want to show fairly faint stars, say 10th magnitude, for a nova search, an exposure of two to five minutes may suffice. If you want to show the starclouds and nebulae of the Milky Way, you might have to expose for 45 minutes or more (unless light pollution makes the Milky Way invisible altogether). Each slide would be called "properly exposed" for one purpose — but rather useless for the others. The significant detail (bright stars, faint stars, or Milky Way) must lie in the middle of the film's range of densities, rather than at the light or dark end.

How can you recognize a properly exposed slide or negative? Two rules of thumb apply — one for slides and one for negatives. If you can see everything you want to see in the slide when you place the slide on a bright lightbox background (without blocking the area around it), it's properly exposed. If you can read fine newspaper print through the darkest important area of a 35mm negative held an inch from the print, it's properly exposed. Slides that are much darker will look beautiful when viewed with a slide projector in a darkened room, and negatives much darker than this will yield successful prints. Slides generally washed out in color are overexposed. Negatives without detail in important shadows (that is, dark areas) are underexposed.

Let's just apply these criteria to a few astrophotos and see how they work. Imagine you have taken some slides and negatives of Jupiter. All of them are in good focus, but some are darker and some are lighter because you varied the exposure. How can you find out which is the best exposure? Place the slides on a lightbox and look at them from 10 to 14 inches away. Ask yourself, "Which is the *darkest* slide which is still light enough to show everything I want to see?" That one is the correct exposure. Although much darker pictures still look good when viewed with a projector, they *are* underexposed and don't represent the best image the film can produce.

Now examine your negatives. You can, of course, read through their clear background areas, but those are not the "significant detail " areas. Choose a negative where the image of Jupiter is just light enough to read through. Now, if you want to show Jupiter's moons, you'll need to expose longer and Jupiter will become too dark. Jupiter is no longer the significant detail, the subject of the picture.

The same criterion applies to star pictures and Milky Way pictures, moon and comet pictures. It provides a midrange density of about 1.0 to 1.5 in slides, and a density of 1.0 to 1.5 in negatives, insuring that the film is operating in its best performance range.

Exposure, then, boils down to letting the right amount of light reach the film. Exposure time, of all the ways of controlling light, is most variable: In astrophotography, the exposure usually lies somewhere between 1/1,000 second to about 1,000 minutes! By opening the shutter for a long or short time, you control how much light strikes the film.

BRIGHTNESS "B" VALUES FOR CELESTIAL OBJECTS

Lunar Phases:	
crescent moon (2-3 days)	10
crescent moon (4-5 days)	20
quarter moon	40
gibbous moon	80
full moon	200
Earthshine	0.01
Lunar Eclipse Features:	
full moon	200
edge of umbra	0.05
midtotality (varies)	0.005
Planets:	
Venus	2,000
Mars	60
Jupiter	30
Saturn	10
Uranus	4
Solar Disk:	10,000,000
Solar Eclipse Features:	
prominences	100
inner corona	50
middle corona	5
outer corona	0.5
eclipse sky	0.01
horizon at eclipse	0.5
Deep Sky Objects:	
middle of Orion nebula	0.001
most nebulae	0.0001
middle of M-31	0.0001
most galaxies	0.00001
Milky Way	0.00001
perfect country sky	0.000002
Earth Comparison Objects:	
blue sky	1,000
summer scene	250
winter scene	100
normal room (night interior)	2

There are limitations, however. The object you're photographing may move or change, or the night may not last long enough to finish a long exposure. Exposures shorter than 1/1,000 second are rare. Few mechanisms are quick enough, and few astronomical subjects are bright enough, to allow shorter exposures.

Besides exposure time, you can control, with some limitations, the efficiency of the optical system that forms the image. This efficiency is given by its effective focal length divided by the aperture of the optical system — the so-called f/number. Quality lenses are available in f/numbers as small as f/1. Lots of light comes through such a lens; it's called "fast" because you can make the exposure time fast when there's lots of light available. You might not want a fast lens though; you may want an optical system with a long focal length so that you get a large image — of the moon perhaps. The focal length of telescopes is most often between 6 and 15 times the aperture — but for big images you may want to use extra optical elements to increase the focal length to 100 times the aperture. The image brightness depends on the square of the focal ratio. Between f/1 and f/100 is a range of 10,000 times in image brightness.

Films are not equally sensitive to light. The fastest (so-called because the exposures with them are fast) are about 1,000 times more sensitive than the slowest. Slow films offer certain advantages, however; they are less grainy, and the image on them can be sharper. Films are rated for speed by an "ASA rating" determined by the manufacturer in accordance with specifications of the American Standards Association. The fastest films are ASA 1600, and the slowest ASA 1 or 2. You should choose a film first on the basis of sharpness and then on the basis of speed, if the exposure turns out to be impractically long with a slow (but sharp) film.

Finally, the brightness of the object you intend to photograph determines how you will photograph it. The brightest subject in astronomy (our sun) is about 10 trillion times brighter than a similar patch of pitch-black rural sky! The brightness of the object will force you to choose a film, an f/number and an exposure capable of producing a correctly exposed film. You might have to make very tricky tradeoffs in terms of cost, exposure, sharpness or practicality to do this. That's part of the fun!

Obviously, these factors are related. They all influence how much light reaches the film or how the film responds to it. You can, for example, decrease the amount of light reaching the film by changing the f/number (or by your choice of telescope, camera lens or eyepiece), but compensate by increasing the exposure time. The f/number is usually rather difficult to control in lunar or planetary photography because you have to select a focal length that gives you a large enough image. And if you're making deep sky pictures, your telescope or camera lens will set your limits for you. In film choice, you're restricted to relatively fast films.

You have no control over the brightness of astronomical subjects. While this is probably frustrating to studio photographers going into astrophotography, everyone else takes it for granted! The variable that you really control is exposure time. Within limits, you can keep the shutter open as long as you have the energy to stay awake to guide the telescope!

It turns out that one simple mathematical equation neatly and tidily ties all the exposure variables together. That equation is:

$$E = \frac{f^2}{S \times B}$$

The equation is set up to give the exposure time (E) in seconds. The f is the f/number (focal ratio) of the optical system, and S is the speed of the film in ASA units. Finally, B is the brightness of the celestial object. You'll find a table giving the B values for many, many celestial subjects on page 49.

Let's work a few examples to get the feel of the relationship between the exposure variables. Imagine that you want to photograph the first quarter moon with an f/10 Schmidt-Cassegrain using Ektachrome 64. If you look up the B value for the first quarter moon, it is given as 40. Plug the numbers into the equation:

$$E = \frac{10^2}{64 \times 40} = \frac{100}{2560} = 1/25 \text{ second}$$

Since the result is in seconds, the exposure should be approximately 1/25 second. Most cameras don't have 1/25 second on the shutter speed dial, but 1/30 is close enough. In fact, you'll find that bracketing your exposure (as photographers call the practice) is often necessary. Try 1/15 and 1/60 second exposures also, and if it's your first try at astrophotography, try the extremes of 1/8 and 1/125 also. You may be wondering why, having just done all this math to find the exposure, we immediately tell you to try all these other exposures? The answer is that you don't know — precisely — what the real f/number of your telescope is, what the real speed of the film is, and how bright the object is after its light gets through the atmosphere. The atmosphere may be transmitting as much as 75 percent and as little as 25 percent without the difference being visually obvious. Your optics may be a bit dirty — or cleaner than the average optics the equation works best for. Finally, if you leave your film in a hot place for a couple of days, its speed changes — perhaps even doubling. As a result, it's best to bracket until you gain experience.

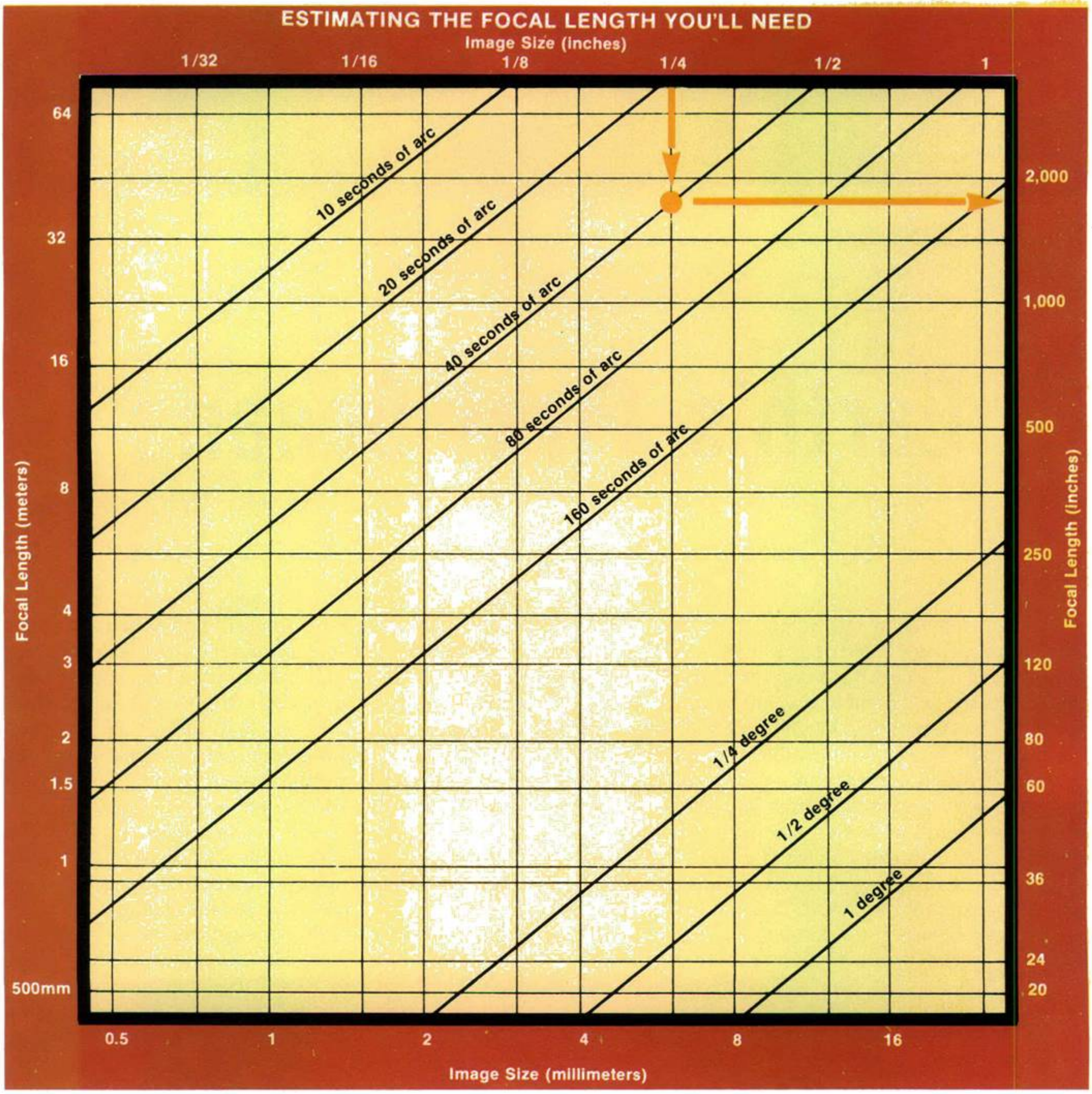
Now, let's say you want to photograph the Milky Way with your 28mm wide angle lens. It's an f/2.5 lens, and you're going to use Ektachrome 200 film. The table gives the Milky Way brightness as 10^{-5}. Plug in the numbers:

$$E = \frac{(2.5)^2}{200 \times 10^{-5}} = 3{,}125 \text{ seconds}$$

The exposure is going to be pretty long — 3,125 seconds is 52 minutes. At this point you may be asking yourself if the slide came out a little darker than it should, wouldn't that be all right? Of course it would; in fact, an exposure of 15 to 20 minutes will probably give you a picture to be proud of! But perhaps you'll rethink the project a bit and try the equation again, using your 50mm f/1.4 lens instead:

$$E = \frac{(1.4)^2}{200 \times 10^{-5}} = 980 \text{ seconds}$$

The new exposure is about 16 minutes, reducing your temptation to purposely underexpose. You're also surely wondering about reciprocity failure: Doesn't that mean the film doesn't record



Suppose you want to photograph Jupiter so that the image on your film comes out 1/4 inch (6mm) in diameter. Locate 1/4 inch on the chart, move down to the slanting line representing Jupiter's angular size (about 40 seconds of arc), and then move over to one of the focal length scales. You can read off either about 1,600 inches or about 40 meters. With an eight inch telescope, the focal ratio would have to be 1,600/8 = 200 to give you a Jupiter image 1/4 inch in diameter.

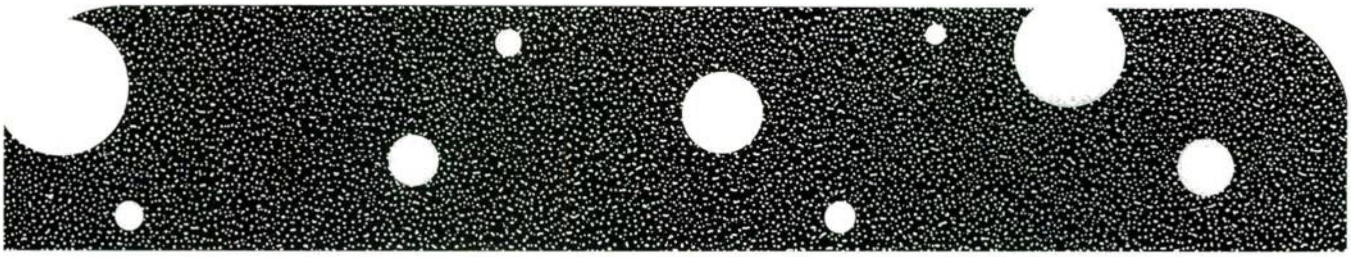
as well for long exposures? It does, indeed; however, the B value already contains an automatic correction for average reciprocity failure in films. If you find after making several exposures that you need more or less exposure than the equation tells you, simply adjust your exposures. The equation will get you off to a good start, however.

After you've obtained good results, you can refine the B value for your particular equipment. From the exposure data, you can calculate the best value — for you — of B from the equation:

$$B = \frac{f^2}{S \times E}$$

If you find that your B value varies from the one given in this article, don't worry. There are enough variations in equipment that disagreement by a factor of 2 or 3 is quite reasonable and common. Use your B value with your equipment if it works for you.

Remember that the real value of the equation is that it gives you a starting place. "How long should I expose?" is a question almost too frightening to face when the exposure might be anything from 1/1,000 to 1,000 seconds! With a starting figure that's almost certain to produce a good result, providing you bracket your exposures, you can proceed with confidence in your astrophotography.



STELLAR FRONTIERS

Earth's First Oceans

by
Herbert Frey

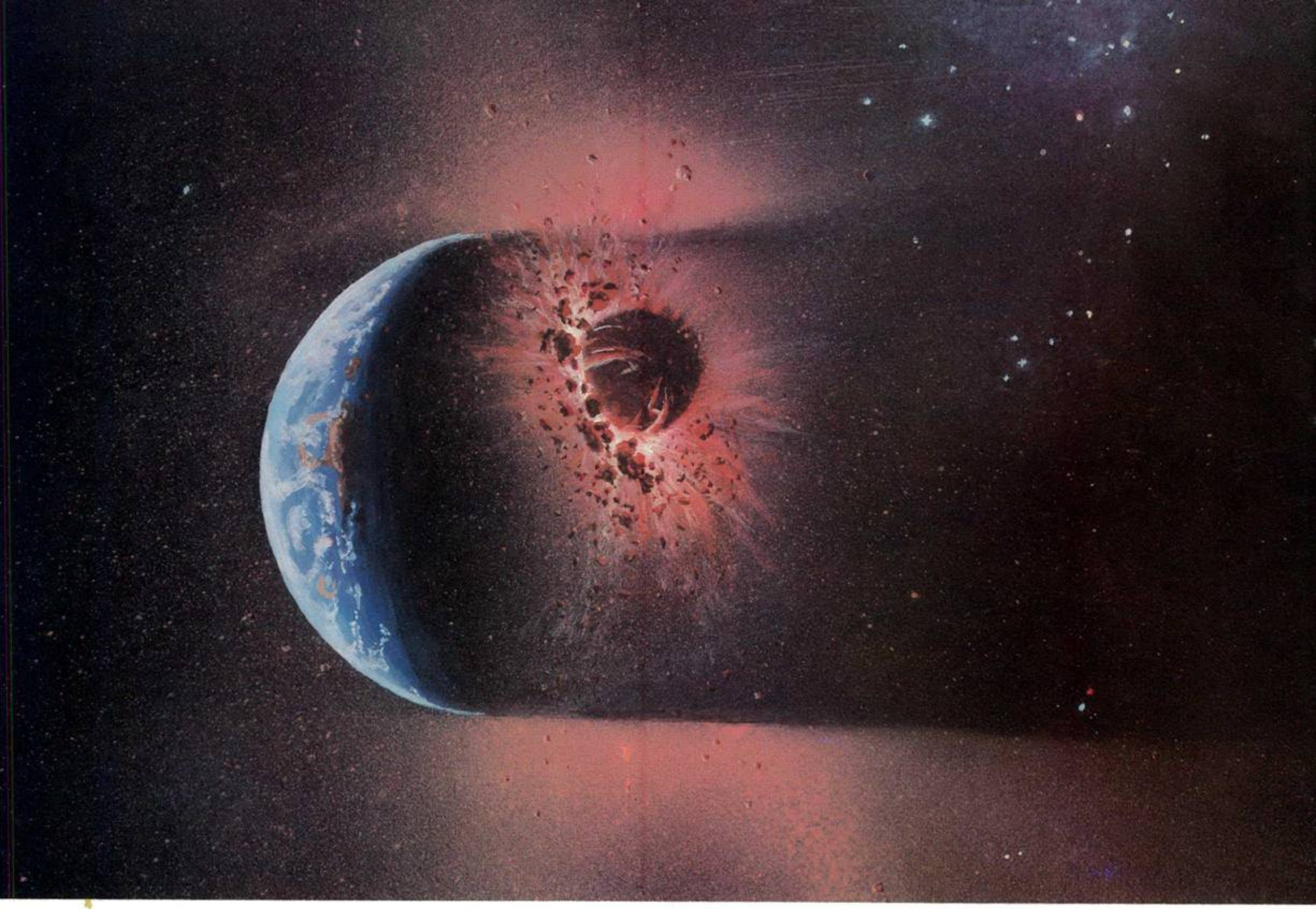
To the television eye of an interstellar space probe approaching Earth, our planet would appear dominated by the oceans that cover nearly 3/4 of the globe. Earth is, in fact, the only world in this planetary system with large bodies of standing water. This is a consequence of its very favorable location in the solar system, where the distance from the sun and the buffering effects of the atmosphere combine to keep temperatures between the boiling and freezing point of water. But where did the oceans come from? How long have they been part of the surface of Earth? The water which fills the depressed regions of the world was originally part of the rocks from which Earth formed. A more difficult question is: How did the ocean *basins* form?

There is a very basic division to Earth's crust. About 40 percent of the surface is high standing, lightweight rocks which make up the continents. The remaining 60 percent is made of low lying, denser or heavier rocks, very similar to the lavas that erupt from the volcanos of Hawaii. These are low lying rocks for the most part covered by water; they floor the oceans and occasionally emerge as volcanic islands. The origin of this *crustal dichotomy* or division is a long-standing and very important problem in the study of Earth; it's often called "the problem of the origin of continents". Two extreme views are that either present continental land masses are the much-altered remnants of original continental crust, or else the low density crust has been progressively generated over time.

Until recently, the "progressive creation" view prevailed. Geologists thought that continental crust was slowly generated by partly melting the rocks from Earth's mantle. On a smaller scale, this process can be seen in the volcanic mountains near deep ocean trenches. According to modern plate tectonics, these trenches are the site of ocean crust *subduction*, where dense oceanic plates are pushed down into the mantle under the overriding edge of a continental plate. As the slab of crustal material descends into Earth, frictional heating leads to increased melting of the deeper layers. Molten rock then works its way to the surface to erupt as lighter-weight crust onto the ocean floors, or onto the leading edge of the continental block. While this process is capable of producing impressive volcanic mountains like the Andes and island arcs like Japan, modern evidence suggests this is mostly recycling older crustal material rather than generating entirely new crust. Now, however, new studies favor the view that today's continents are related to original low density crust dating from earliest Earth history.

The crustal dichotomy of Earth has its parallel on the other terrestrial planets. The moon, Mercury, Mars, and perhaps also Venus have two distinct types of crust. There are bright, heavily cratered (and therefore very old) *highlands*, and the generally flatter, smoother, less cratered *maria*. The highlands are like the continents of Earth in that they are the older type of crust, and are low density or lightweight rocks. By contrast, maria are younger and are chemically rather similar to the lavas that floor Earth's oceans. What was the origin of this crustal dichotomy on other planets? Does a

The oceans are fundamentally important to life on Earth. Without them, this planet couldn't have evolved its present pleasant atmosphere, nor disposed of the carbon dioxide that makes Venus inhospitable. What might the oceans have looked like three of four billion years ago on a far more cratered Earth — an Earth devoid of life, and cloaked in an unbreatheable atmosphere? Artwork by Mark Paternostro.



Earth's crust did not survive intact through the long period of bombardment that followed Earth's formation. The crust was broken up by hundreds of small impacts and perhaps by a few gigantic impacts from objects the size of small planets. Besides ejecting sufficient crustal material into orbit to form Earth's moon, such giant late impacts could have weakened any initial rigid shell-like crust so that crustal plates could form. Artwork by William Hartmann.

similar origin exist for the separation of continents and ocean basins on Earth?

Our moon is most instructive in this case, as its earliest history (including the time when this crustal dichotomy was established) is much better preserved than on any other planet. The entire moon was highland type crust 4.4 to 4.6 billion years ago. This surface was bombarded by immense, asteroid sized planetesimals (see "The Moon's Early History", ASTRONOMY, September 1976), probably the material left over from the formation of the planets. These explosive impacts formed gigantic craters called impact *basins*, which were over 190 miles (300km) wide. (A good example is the Orientale structure, which formed about 3.95 billion years ago on the moon. Though Orientale is the freshest — and probably the last — of the giant impact scars on the moon's surface, traces of at least 30 older basins remain preserved as double or multiple ringed craters.)

Some scientists believe the "basin forming period" on the moon was short, and that most of the 30 major basins formed about four billion years ago — give or take 100 to 200 million years! Evidence for this comes from the apparent absence of any *whole* rocks older than this time among the samples brought back by Apollo astronauts. Only tiny rare fragments have ages greater than four billion years. These lunar scientists think the concentrated bombardment of several dozen asteroid sized planetesimals so highly pulverized and fractured the lunar surface that the radioactive "clocks" of the moon's surface rocks were all "reset". The rock ages then record the date of intense cratering rather than the period of formation of the crust. Other scientists dispute this view, claiming that the lunar basins were produced as a part of a prolonged "sweeping up" of the leftovers from planet formation. In this case, the impacting of the lunar surface by these large planetesimals was not a specific event, but a process lasting over a half billion years. The basins we see would then be only the last few dozen or so that formed near the end of the sweepup.

Large impact basins such as Orientale are also seen on Mercury and Mars. These planets experienced a similar bombardment by very large planetesimals, probably early in their histories. Because there are no returned samples yet, we don't have dates for Mars and Mercury as we do for the moon. But studies of the orbital paths of large planetesimals in the inner solar system — especially by George Wetherill of the Carnegie Institution in Washington — show that planetesimals would either have impacted one of the terrestrial planets (or the moon) or been ejected from the solar system during the first half billion years or so.

The important point of Wetherill's research is that *Earth* was also bombarded *by the same type of objects at the same time as the moon.* Because both Earth and the moon are close together in the solar system — compared to the distances between planets — both experienced the same flux of impacting bodies. Indeed, Earth would have collected more of the planetesimals because of its larger gravity field. The disruptive effects of such immense impacts would have been even more severe on Earth than on the moon.

What became of these impact basins? On the moon, the 300 mile (500km) wide, 3 to 6 mile (5 to 10km) deep craters became the sites of extensive volcanic activity. Radioactive heating of the interior of the moon produced a magma with properties similar to the basaltic lavas that flow from the Hawaiian volcanos. As the volume of hot melted rock increased, it rose toward the surface. Flowing most easily through the badly fractured crust below the large impact basins, the magma finally spilled out onto the surface in hundreds of individual floods, coating the floor of the impact basins with a few kilometers of cooling lava. The density of these low lying volcanic rocks was higher than that of the surrounding highland rocks. This period of lava eruption (which occurred in spurts from four to about three billion years ago) was the final active event of lunar evolution. The net effect was to change the lunar surface from a global, highland crust of low density rocks to one with a two-fold nature. Thirty percent of the moon's surface is now a higher density lavalike crust, erupted into the deep impact basins.

A similar sequence of events is recognized for the early history of Mercury and Mars. Cooling of the planets led to formation of a global highland type crust, which was then broken in places by the formation of giant impact basins like those which formed on the moon. These basins were subsequently flooded by denser lavas from the interiors of the planets.

What about Earth? Can we expect this pattern of events to have occurred here as well?

The first question to answer is: Did Earth begin its history with a global lightweight crust — like the highlands of the moon, Mars and Mercury? Evidence suggests that it did. The moon's global crust was the result of the original *differentiation* of that body. Shortly after it formed, the moon melted — at least in the outer several hundred kilometers. The cooling of this molten layer led to formation of the global lightweight crust, as the low density rocks floated to the top of the molten material. The heat source for the melting was two-fold: 1) radioactivity inside the moon was slowly releasing heat, while 2) the final growth of the moon was yielding *accretional* heat. The last 10 percent or so of the mass that formed the moon was collected very fast because the gravity field of the moon was nearly fully developed. Material crashed into the moon at such high velocity that it released enormous amounts of heat.

Accretional heating during the final stages of growth was even more severe for the larger terrestrial planets. Their greater gravitational fields caused incoming material to impact even faster than material hitting the moon. Therefore, even more heat would have been released. Earth (largest of the terrestrial planets) should have been most throughly heated by this process. Paul Lowman, of NASA's Goddard Space Flight Center, has shown that Earth underwent a more complete differentiation and formed a lightweight *global* crust very early in its history. The crust would have been similar to the continents of today, but it would have covered the entire planet — like the original lunar highlands. Lowman and other scientists argue that modern continents are the remnants of a much earlier global crust. In its very earliest time, Earth was like the moon, Mars and Mercury.

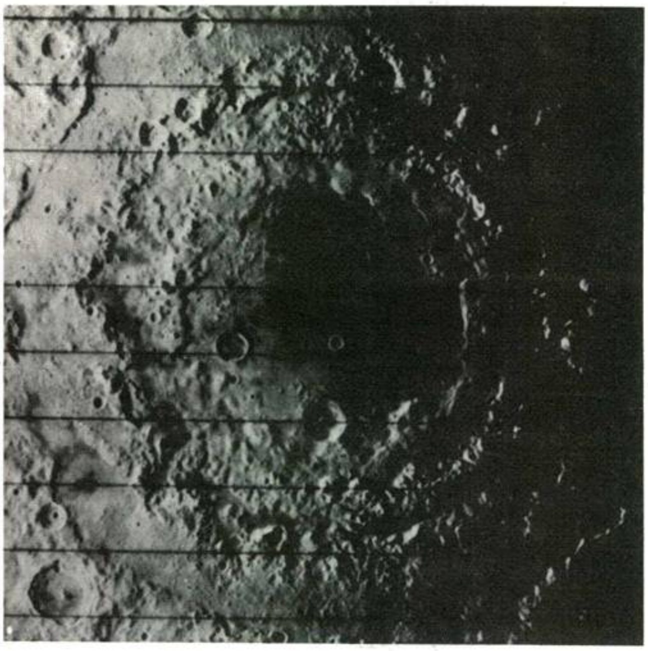
But how did the oceanic crust — which now covers 60 percent of Earth — ever form? Today, new oceanic crust is generated as a part of plate tectonics: It erupts along giant rifts in the surface, spreading outward and forming Atlantic type seas. In order to form, however, this new crust requires compensating destruction of crust elsewhere on Earth. Continental crust is too buoyant to be easily destroyed — it literally floats on the denser rock — so it's the older *oceanic* crust that is recycled by being thrust back down into the mantle at the ocean trenches. Plate tectonics cannot operate, therefore, unless high density oceanic crust *already* exists. Plate processes cannot convert a *global* continental crust into one having only 40 percent lightweight rocks. The crustal dichotomy must have been established first.

Since Earth could not have escaped the basin forming bombardment which occurred on the moon four billion years ago, it's possible to calculate how many giant impact basins formed on Earth by using the moon as an "impact counter". Allowing for the much greater gravitational field of Earth, which would have pulled in more objects, leads to a startling view of early Earth. While major Orientale type basins cover only about 40 percent of the moon's surface, the *hundreds* that formed on Earth turned more than 50 percent, and perhaps as much as 70 percent, of Earth's original global crust into giant, deep depressions. Typical sizes for the terrestrial basins run 600 miles (1,000km) across and up to 3 miles (5km) deep (after the crust resettled).

Earth's crust has always been thinner than the moon's, so molten rock was closer to the surface at the time of basin formation. Within a few thousand years — the blink of an eye in Earth's history — lava would have worked its way through the badly fractured floors of the largest basins, bringing higher density rocks to the surface. Basin-filling probably occurred as dozens of thin individual flows. Some 3.9 billion years ago, then, Earth looked very much like the moon, though more of its surface would have been covered by dark lava mare surfaces than the moon. The crustal dichotomy — high standing but lightweight rocks, and low lying but denser rocks — became established very early in the history of Earth. Implications for the evolution of life on Earth are very important.

It's generally agreed that life originated in the seas — in warm, shallow bodies of water that must have existed long ago. There, much of the early chemical fabrication of the precursor life molecules took place. The first complex organic compounds formed, and there, the earliest self-replicating systems originated. Fossil impressions of relatively advanced life forms are found in rocks dated as 3.5 billion years or older. This implies that the *chemical evolution* to biological systems took place much earlier, because a significant period of biological evolution must have occurred before 3.5 billion years ago. Oceans of some kind must have been in existence for several hundred million years before this. But major basins formed first on Earth four billion years ago — some probably before this — and these major impact depressions would have rapidly become the first seas as well, if water was available. Formation of a 3 mile (5km) deep, 600 mile (1,000km) wide hole in Earth's crust would provide a natural drain for the liquid water. But was there liquid water four billion years ago?

Most of the volatiles of Earth — including water — were degassed early in Earth's history as a natural product of the differentiation that occurred then. Cooling molten rock releases the gases that were once part of it. As the crust of Earth first formed more than four billion years ago, large volumes of carbon dioxide, water and other gases were probably exhaled. By the time of formation of the major impact basins, liquid water could have been abundant. Even if a global ocean of several kilometers depth had covered early Earth, it would have provided no barrier to a 19 to 31 mile (30 to 50km) wide asteroid traveling at more than 9 miles (15km) per second. The planetesimal could pass through the liquid layer in a fraction of a second and strike the solid crust below, blasting a deep impact basin. After the impact, water would drain back into the basin. Surrounding highlands and crater rims would stand above the global ocean as dry land. Eventually crustal areas would have become continents, while the basins became oceans. Pieces of highland not impacted by the large planetesimals would, in this view, be moved about by later plate tectonic processes, finally being assembled into massive supercontinents like Pangaea, and later broken up into today's continents and oceans.



Like a giant bullseye blasted in the lunar surface, the Orientale Basin resulted from the late bombardment of the moon. This basin is huge: The outer ring — the Cordillera Mountains — is some 600 miles in diameter. Within the outer ring, the Rock Mountains form a scarp some 400 miles in diameter. The beautifully preserved texture of the surface and sharpness of the mountain ranges suggest that Orientale is one of the youngest lunar basins. NASA photograph.

Thus a basic division between land and sea was produced early in our planet's history — early enough to set the stage for the complicated evolution of simple chemicals to the complex life forms seen in 3.5 billion-year-old rocks.

What might have happened if the basin forming bombardment had not occurred? Although there might still be life, it would have been confined to the global ocean. Missing would be the large blocks of dry land on which air breathing life forms would later evolve. Mammals would probably have never arisen in such a water world. If Earth had had less water, it would have been a dry planet with no deep oceans. Advanced life forms would have been rare. Most life would have been simple types confined to a few pools of water filling the normal sized craters. In either case, it's safe to say that the evolution of life on this world would have been drastically different from what it was. The very existence of humans on Earth is due in part to the shaping of the early environment by the intense basin forming bombardment of four billion years ago. Without that critical alteration of the early crust, there could have been no major oceans — and probably no humans to investigate and question the origin of the first ocean basins and continents of Earth.

Herbert Frey obtained his Ph.D from the University of Maryland in 1977; his thesis was on the early crustal evolution of Earth, using information derived from comparative studies of the planets. Frey currently works at Goddard Space Flight Center and teaches at the University of Maryland.

ASTRO-NEWS

Latest News From the World of Astronomy

Discoveries Confirm Antarctic Has Vast Meteorite Deposits

Geologist William Cassidy has reported finding 21 meteorities within two hours of setting up camp in an ice covered area in the Transantarctic Mountains.

That he was able to almost pinpoint where the meteorites would be found would seem to confirm his theory (stated after his last expedition) that meteorites could be found on very old ice surfaces that have lost their snow cover, perhaps because of strong winds. On this last expedition Cassidy led the group that found the largest meteorite ever discovered in Antarctica.

Dr. Mort D. Turner of the National Science Foundation's Division of Polar Programs said this is the first time anyone has come up with an idea of where meteorites should be found without actually seeing one fall.

Most of the newly found meteorites are small; the largest weighs about 17 pounds. They were found near Allan Nunatak, an isolated mountain peak protruding through glacial ice in Victoria Land. The site is about 130 miles northeast of McMurdo Station, the principal United States scientific outpost in Antarctica.

Dr. Cyril Ponnamperuma of the University of Maryland, one of the world's foremost meteorite experts, termed Cassidy's achievement "a fantastic find. There are only about 2,000 meteorites in the world's collection, and to find 21 at one time is truly exciting." Ponnamperuma, who specializes in studying organic compounds in meteorites, said the only laboratory evidence scientists have for the existence of any organic matter prior to the beginning of life on Earth is in meteorites.

Meteorites are masses of stony or metallic material that have fallen to the ground after surviving their fiery flight from space through Earth's atmosphere. Scientists believe meteorites are chunks of broken up planets or natural satellites, or are pieces of matter that never formed a larger body.

Commenting on the find, Ponnamperuma said, "Without the need for going to the moon we now have the opportunity of collecting extraterrestrial materials that have been preserved in excellent condition by the extreme cold conditions in Antarctica."

The newly found meteorites were picked up with special gloves, placed in sterile bags and put in special metal boxes loaned to Cassidy by NASA, which used them in the collection of lunar samples. The meteorites will be sent to meteorite curating centers in the U.S. and Japan for later distribution to scientists. U.S. scientists have been working with researchers from the Japanese National Institute of Polar Research in Tokyo. The U.S. effort is managed and funded by the National Science Foundation.

X-Ray Telescope May Get Okay Under Next Budget

A large x-ray telescope is one of several space projects being considered for the federal budget that would be proposed in January 1979, for the year ending Sept. 30, 1980.

Called the Advanced X-Ray Astrophysics Facility (AXAF), it would draw on designs for the Space Telescope and the second High Energy Astronomy Observatory (HEAO-B). AXAF, now being studied at Marshall Space Flight Center, would incorporate design features of both.

Because it would have the same pointing and operating requirements, AXAF could use the same power supply, solar cells, attitude control, and command and data systems as the Space Telescope. Just how much could be transferred to AXAF is being determined now.

Different optics would be required because x-rays would pass straight through the parabolic mirror of the Space Telescope; therefore, optics similar to HEAO-B must be used. These optics employ four tubes of glass nested in each other, and coated with a thin layer of nickel.

The tubes are slightly curved — a combination of parabola and hyperbola — to focus the x-rays by grazing incidence. This is the same effect as when a normally transparent sheet of glass becomes mirrorlike when viewed almost edge-on.

AXAF probably will have a four foot aperture. Combined with new sensors, it should produce images up to 10 times better than those of HEAO-B.

"It will be possible," said Dr. Martin Weiskopf, Marshall's scientist in charge of AXAF, "to detect and resolve clusters of x-ray emitting galaxies at the extreme reaches of the universe, and to study their evolution over times comparable to the age of the universe."

There are no cost estimates yet, and launch probably would be in the mid-1980s.

A three foot ultraviolet survey telescope called Starlab is also being considered for the fiscal year 1980 budget. It probably would operate attached to the Shuttle and use test hardware from Space Telescope development.

Other items being considered for the next budget include:

- Ion drive for rendezvous with a comet;
- A large helium cooled, infrared telescope to operate with the Shuttle and Spacelab;
- A Venus orbiter with synthetic aperture radar to produce optical quality images of the Venusian surface, despite its cloud cover;
- A Viking-Mars follow-on mission, possibly involving a roving lander, and
- Gamma ray and cosmic particle observatories that would operate with the Shuttle and Spacelab.

Space Shuttle May Affect Upper Atmosphere Layers

Upper atmosphere pollution by the Space Shuttle, and other effects of its presence in orbit, will be studied by NASA as part of a multimillion dollar research project. Included are funds for development and use of equipment to analyze the effect of shuttle exhaust on the upper atmosphere.

Temporary decreases in the electron density of the ionosphere, caused by rocket exhaust, have been noted before. NASA is now concerned with what effect the shuttle, which will release a great deal of material from its maneuvering rockets, will have on this area.

The effect of shuttle exhaust will also be studied to avoid the problem of gases coating the lenses of the optical telescopes that will be carried on some Shuttle missions.

A Plasma Diagnostics Package (PDP) will measure concentrations of ions around the ship and how these densities are affected by the shuttle. The instruments will also measure the "wake" the ship leaves as it moves through the ionosphere. This wake will later be compared to the wake planets leave as they move around the sun.

An initial NASA grant of $2.5 million to physics Prof. Stanley D. Shawhan, of the University of Iowa, will provide for development and initial production of the PDP. It is scheduled to be used on Shuttle Operational Flight Test Four (OFT-4) in December 1979. The instrument will be released from the craft as an independent satellite on the Spacelab II mission in April 1981.

On OFT-4, the PDP will be attached to the shuttle's extension arm, which will project the package out to 50 feet from the orbiter, swinging it into different positions relative to the craft. The PDP will record the electric and magnetic waves caused by the shuttle's passage through the ionosphere, and the ion density around the craft.

The PDP will also be used to prepare for the shuttle's radio telescope missions by recording radio sources that originate within the shuttle. Properly identified, these signals can be ignored during radio telescope missions.

"Our project is to build a package of instruments which can, in effect, act as a subsatellite of the orbiter," Shawhan said. "This way it can be apart from the orbiter to detect its effects, in addition to studying other phenomena of the ionosphere.

"What we will be doing is measuring the plasma, the ionized gas, up there," Shawhan said. "The shuttle will operate in the 200 to 400km (125 to 250 mile) range in the ionosphere. There is naturally ionized gas up there, but the shuttle will add more."

The shuttle will produce gas — predominantly water vapor — when it fires its rockets and when it releases water produced by its fuel cells. The fuel cells, which provide internal power for the shuttle, can produce 135 gallons of water every four hours during heavy use. Current plans call for flushing the waste water into space. Water is also released from the flash evaporator, part of the internal cooling system.

After the water vapor is released, solar radiation breaks it apart and ionizes the oxygen. The hydrogen escapes into space and the oxygen, at least temporarily, increases the density of the ionosphere.

"The question is, how long will it take this material to dissipate?" Shawhan said. "We think the time scale will be hours, but we can't be sure until we can check it out from orbit. It could be significant if it persists, or insignificant if it dissipates."

The problem of a temporary decrease in the electron density of the ionosphere was noticed after the last Saturn V launch. A group of researchers was gathering data from a satellite when the signal suddenly altered. Later investigations showed the signal had passed through the exhaust from the Saturn V.

"This affected a several hundred square kilometer area," Shawhan said. "Later, a rocket was sent up with a canister on board which was exploded in the ionosphere, producing water vapor and other materials similar to rocket exhaust. The electron density of the ionosphere decreased and it took about three hours for the effects to dissipate, as observed from the ground. The PDP, however, will be able to gather data on the orbiter's effects 'at the scene'.

"There is a two-stage phenomenon involved here. First, let's say the shuttle releases water vapor and propellant, either from its rockets or from the evaporator. This material — as much as several hundred pounds of it — is released into the ionosphere.

"The free electrons in this area are attracted to all this material — especially the water vapor. The ions become molecules, and the area is temporarily depleted of free electrons.

"Solar energy, however, breaks the water molecules apart. The oxygen tends to stay, but the hydrogen escapes into space. Any heavier molecules, perhaps from the propellant, sink.

"The oxygen atoms become ionized and tend to disperse," Shawhan said. "The result is that first you have an increase in the gas density in the area, and then a decrease in the ion concentration. Eventually, you may have an increase in ion concentration. This reaction could affect a several hundred square kilometer area."

While the effects of single space shots seem to dissipate, NASA intends to use the shuttle as the "workhorse" of space. Plans call for several hundred flights by 1992 which, in total, will release hundreds of tons of gas into the ionosphere.

"We don't know how bad the problem will be. At the worst it could add an entire new layer to the ionosphere, but we just don't know," Shawhan said. "NASA plans to fly our particular payload four or five times."

If the gas from the orbiter dissipates too slowly, changes might have to be made in the shuttle design.

"The fuel cell, for example, produces a great deal of water," said Shawhan. "Current plans call for the equivalent of throwing it overboard by jettisoning it into space.

"If this becomes a problem, the water could simply be saved inside the ship somewhere and disposed of on earth. The problem is, saving the water will increase weight, decrease payload capacity, and increase costs."

Despite thousands of United States and Soviet space launches in the last two decades, there is no evidence that the ionosphere has been affected in the long run. "From day to day, the ionosphere changes considerably through natural processes," Shawhan said. "I don't think there is anything that has happened there, on a long term scale, that we can point to and say man caused this."

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Corporation Proposes New Lunar Exploration Phase

The United States could return men to the moon as early as 1986 under a program proposed by the Earth Satellite Corp.

Charles Sheffield, vice president of the firm and first vice president of the American Astronautical Society, told the House Science and Technology Committee recently that the U.S. should plan a 20 year space program that would:

- Develop a manned reusable space tug (currently deferred) to support operations to and from geosynchronous orbit, and from lunar orbit to the lunar surface and back. Under Sheffield's plan, the tug should be developed by 1987.
- Start lunar exploration in 1986 to determine what resources could be used to support construction in space. Such exploration would start before the tug was ready, but would rely heavily upon the tug after 1989.
- Establish a combined applications platform (CAP) in geosynchronous orbit by 1993. CAP would support a number of applications missions now carried out by independent satellites, and include a manned crew for maintenance and operations.

Oddly, Sheffield's proposal apparently is not aimed at directly supporting Dr. Gerard O'Neill's proposal to mine the moon to produce power satellite stations. "I do not see this as feasible (in the next 20 years). We must anchor our dreams in engineering reality," he said.

Japan Plans Moon, Venus Space Probes

Probes to Venus and the moon, and regular flights aboard the Space Shuttle are high points of a space program submitted to Japanese Prime Minister Takeo Fukeda by Japan's Space Development Council.

The council's plan covers 76 proposed launches over a period of 15 years, from 1978 to 1992. The lunar probe, using a spacecraft similar to Japan's Exos A satellite, would be launched in 1985 by the Japanese-developed Mu three stage solid rocket.

The Venus probe, also based on Exos A, would be launched in 1990 by an N-2 rocket, based on the United States' Delta. An H-1 rocket would also send an observation balloon to the clouded planet. The Exos A satellite was designed to study Earth's magnetosphere and ionosphere, and carries an ultraviolet television camera.

One to three Japanese engineers or scientists would fly aboard the U.S. Space Shuttle each year under another part of the plan. The council recommended that the first trip on the Shuttle in 1983 concentrate on performing space processing experiments, and that one to three trips follow each year, starting in 1984.

Japan's growing interest in space is demonstrated by recently announced plans for a space exposition in Tokyo starting July 16. The six month, $21 million project will have as its theme "Space — Dream and Hope for Humanity". It will be aimed at the general public with special emphasis on educating children.

Of the four pavilions, one will be dedicated entirely to the Apollo project that put Americans on the moon. U.S. space hardware on display will include a Saturn IB rocket, F-1 and J-2 rocket engines from the Saturn V moon rocket, and Mercury, Gemini and Apollo manned spacecraft.

The other pavilions will cover the U.S. space program as a whole, Japanese space technology, and a simulated space flight.

Course Change for Galileo

Increased weight has forced planners at the Jet Propulsion Laboratory to select a slower route to Jupiter for the Galileo orbiter and probe mission.

The spacecraft was to weigh 3,300 pounds, but has gained 1,023 pounds because of various design changes. About 400 pounds were added when the design of the atmospheric probe was changed to a vented vessel to allow it to survive longer in Jupiter's dense atmosphere.

In order to keep Galileo's rendezvous with the giant planet, it will be targeted to swing past Mars and employ the same "gravity slingshot" effect used by Pioneers 10 and 11. This will make up for the extra weight, but it will take five extra months to get there.

Upon arrival, Galileo's electronics will be protected with the same type of circuitry being developed to protect military satellites from nuclear weapons. Ceramic metal oxide semiconductor (CMOS) circuits were developed out of concern that United States military satellites might be destroyed by even a distant nuclear blast in space.

The need for such circuits on planetary spacecraft was demonstrated by the Pioneer 10 and 11 probes when their own circuits were almost saturated by radiation trapped in Jupiter's intense magnetosphere.

Soviets Develop Their Own Version of the Space Shuttle

The Soviet Union has been conducting landing tests of its own shuttlecraft similar to those of the Space Shuttle Enterprise, according to a top aerospace trade journal.

Aviation Week and Space Technology reported in a recent issue that a Tu-95 Bear strategic bomber has been dropping the shuttlecraft in tests deep inside the Soviet Union. A spokesman for the magazine declined to identify the source of the report, but said it came from a "professional organization".

Dr. Charles S. Sheldon, Director of science and technology policy for the Library of Congress, and the expert called upon by Congress to keep track of the Soviets, said he could not discuss the report.

"There's nothing I can tell you," he said. Such information "has to come from sensitive areas, and I never talk about those".

By contrast, Sheldon said in June 1977, "I have not one whit of evidence, one way or the other."

According to the article, the shuttlecraft would be much smaller than our Shuttle. It would probably be used just to support operations with the Salyut space station instead of replacing all launch vehicles as our Shuttle will. Indications are that the craft would comprise the upper stage and would still use throwaway lower stages.

Even so, it would greatly expand Soviet space activities by giving them more flexibility in their orbital operations and the capability of launching larger crews and more supplies.

No launch date was given in the article. The first United States Shuttle launch is set for the spring of 1979.

Space Shuttle Enterprise Starts Launch Vibration Test Series

The Enterprise, the first Space Shuttle orbiter, arrived in Huntsville, Ala., in mid-March for several months of tests to simulate launch vibrations.

The prototype of the reusable spaceplane arrived atop the same Boeing 747 jetliner that carried it aloft for five landing tests last year in California. The tests in Huntsville, at Marshall Space Flight Center, will be equally critical although far less dramatic.

In effect, the tests will make sure that the Shuttle does not shake itself apart during launch. The Enterprise will be mated first to its giant external tank (27 feet wide, 154 feet long) for a series of tests, and then to the tank and solid rocket boosters. It will be the first time the orbiter has been mated to the other components that make up a complete Shuttle.

The tests will simulate five points during the launch: liftoff (full boosters, full tank), booster jettison (empty boosters), and three points between booster jettison and main engine liftoff. Water will simulate the liquid oxygen in the tank. Liquid hydrogen is so light that it will not be simulated.

Only a few hundred pounds of force will be used in making the Shuttle vibrate, but this will be enough for engineers to find sympathetic vibrations similar to an unbalanced tire causing part of a car to shake with the same beat at a certain speed.

After tests are over in November, the Enterprise will be returned to Palmdale, Calif. to be broken down into separate parts. NASA's original plans called for it to be refitted for flight, but President Carter's proposed budget has cut back the Shuttle program.

Instead, the structural test article, an exact duplicate of the second orbiter which will make the first Shuttle launch, will be refitted for space after flight load tests. It is only 3,000 pounds overweight, as opposed to Enterprise's 6,000 pounds of excess structure.

The Space Shuttle Orbiter Enterprise is shown being hoisted into the dynamic test stand where it will undergo a series of ground vibration tests. The testing is taking place at NASA's Marshall Space Flight Center in Huntsville, Ala. NASA photograph.

Organization Planned For Space Telescope

NASA plans to establish a Space Telescope Science Institute to manage space science operations for the eight foot (2.4 meter) Space Telescope now under development.

The institute would be responsible for coordinating selection of observation targets and distribution of data. Actual control will be through Goddard Space Flight Center. The Space Telescope will be launched by the Space Shuttle in 1983 for the first of three planned five year missions.

"This kit contains everything an astronomer needs — telescope, camera, a galaxy . . ."

Boy Scout Merit Badge

Many an adult has found a start in the hobby or even career of astronomy through exposure as a Boy Scout. Through the years, 175,000 scouts have earned astronomy badges since they were first offered in 1911.

Some former scouts distinguished themselves by becoming astronauts. Of the 73 pilots and scientists named as astronauts since April 1959, 59 were scouts! Neil A. Armstrong, an Eagle Scout from Wapakoneta, Ohio, was the first man on the moon.

Astronauts, astronomers or space study enthusiasts all can start early through the merit badge program of the Boy Scouts. Requirements for the astronomy badge are centered around several areas: telescopes, the planets, constellations, the sun and the moon. There is no mandatory sequence that must be followed. A scout can do a considerable number of the observations for the various areas in one night.

To qualify for the astronomy merit badge, the scout must sketch the face of the moon, showing location of at least five seas and craters. During a single week, he sketches the position of the moon at the same hour on three different evenings, explaining the changes he observes. He must also tell his adult volunteer counselor what factors keep the moon in orbit around Earth.

One of two options are selected. He may photograph or locate a planet on a sky map. The scout observes the planet once a week at the same time each night for at least a month, noting changes. As a second alternative, he can find out when each of the five visible planets can be seen in the evening sky during a year and compile the information in the form of a chart or table.

The badge candidate then selects one of three additional options. A sketch can be drawn showing the position of three visible planets (such as Venus, Mars or Jupiter) in the sky at the same time once a week, for at least four weeks. Perhaps he will choose to use a compass and record the direction to the sun at sunset for at least a month in spring or fall, or six to eight weeks in summer or winter. Or with the aid of diagrams, he may explain the relative positions of the sun, Earth and moon at times of lunar and solar eclipses, and also at new, first quarter, full and last quarter phases of the moon.

The scout (whose age may range from 11 to 17 years) lays out a true north-south line or meridian using the shadow of a vertical pole in sunshine. On another day, the same pole and line are used to measure the altitude of the noontime sun, enabling him to determine his latitude.

He must identify at least 10 constellations (of which four must be in the zodiac), and at least eight conspicuous stars, five of first magnitude. An explanation of the Milky Way is given. Another sketch is made showing the position of the Big Dipper and its relation to the North Star and the horizon early in an evening. This is repeated six hours later the same night, with records of date and time made on each sketch.

Using diagrams or a telescope, the scout must explain the difference between reflecting and refracting telescopes. The basic purpose of a telescope is described, along with at least three other instruments used with telescopes.

Astronomy badge candidates then describe the composition of the sun, its relationship to other stars, and some effects of its radiation on Earth's weather. Sunspots and their effects are also discussed. At least one red star is identified, as is one blue and one yellow. The meaning of each of these colors is explained.

A planetarium or observatory is visited, followed by a report to his counselor on observations made during the visit. At least three hours are spent observing celestial objects through a telescope or binoculars, with a report also made on these observations.

The scout concludes by naming different career opportunities in astronomy, along with the preparation needed. High school courses most useful in preparing for an astronomy career are listed.

All requirements must be completed to the satisfaction of the counselor.

Persons interested in serving as counselors can contact local scout council offices for specifics. No scouting experience is necessary, but knowledge of astronomy is, as well as a desire to guide ambitious scouts.

Power Module System May Extend Shuttle Orbit Time

Lockheed Missiles & Space Co., Inc. has been awarded a $350,000 contract to study an orbital power module that would enable the Space Shuttle to operate in orbit for 90 days or more.

The power module, under study for several months by Marshall Space Flight Center in Huntsville, Ala., would use equipment left over from the Skylab program.

In its present form, the reusable Shuttle orbiter can support a basic seven day mission in space. With additional air, water and electrical fuel cell supplies, this can be extended to 30 days. Still, the extra supplies cut into the payload that can be carried and can supply only an average of seven kilowatts of electrical power. Thus, the longer the mission, the less work that can be done per day.

The power module would be placed in orbit and left there for future missions to dock with.

According to Jim Murphy, Marshall director of program development, the module would not be a very "new" system. "Our approach was, and still is, to use as much of the off-the-shelf hardware as possible," he said. "It would be a very straightforward job."

The hardware intended for this role is from the Skylab B Apollo telescope mount, a battery of solar telescopes that would have been used had a second Skylab space station been orbited.

The module would use two backup ATM structures, power conditioning and attitude control equipment. The ATM's batteries would be replaced with more efficient ones developed since Skylab flew. The solar panels would be replaced with an advanced roll-up array developed by Marshall for the ion drive comet probe.

The 20,000 pound module would deliver peak loads of 50 kilowatts of electricity (with an average of 25 kilowatts), and provide the Shuttle with attitude control.

It would take about three years and $100 million to construct the module. Studies indicate that during its 10 year lifetime, it would save $340 million by reducing the number of launches necessary to achieve long durations in space.

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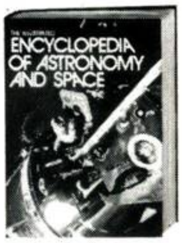
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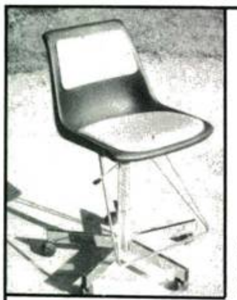
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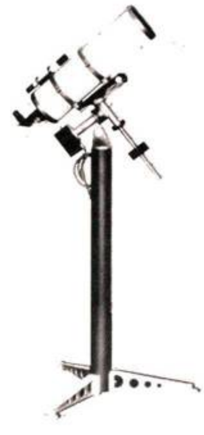

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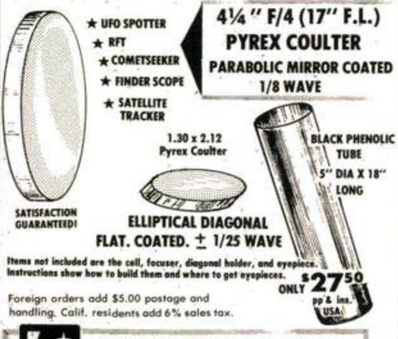

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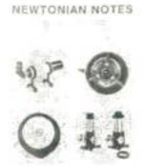

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FOR SALE — Astronomical magazines. Write Charles Doby, 110 Lafayette St., Copiague, NY 11726.

FOR SALE OR TRADE — ASTRONOMY back issues: October 1974 to present. Best offer or trade for toy trains. Write Bob Gluckman, 7299 Dublin Rd., Bergen, NY 14416.

WANTED — Equatorial refractor (300-400x) in good condition. Would like viewfinder, Barlow, slow motion cables. $250.00 tops., Send details (and picture if possible) to Scott Carson, P.O. Box 73, Monroeton, PA 18832.

WANTED — Correspondence with professionals or amateurs interested in serious astronomy and/or astrophysics. Write Scott Coltrain, 8047 Suncrest Dr., Des Moines, IA 50315.

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WANTED — Correspondence with persons interested in study and development of space colonies, and future of industry in space. Discuss merits of various habitat designs, aspects of living in space. Write Michael E. Eckardt, 1807 Vichy Rd., Rolla, MD 65401.

WANTED — Observations, astrophotographs of deep sky objects; correspondence about deep sky astronomy, observing programs. For future publication in "Deep Sky Monthly" and associated research projects. Submit material to David Eicher, Editor, 104 Oakhill Dr., Oxford, OH 45056. Phone (513) 523-5554.

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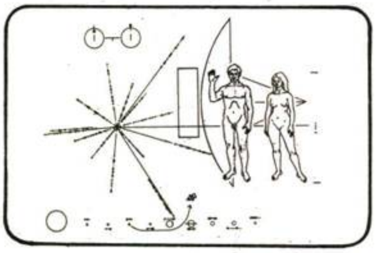

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WANTED — Right ascension circle and lock, and declination circle and lock for 3" reflector. Send price to Marion Hakes, 1505 W. Washington, Bluffton, IN 46714.

WANTED — Contact with anyone knowledgeable or interested in the ancient Druids and their knowledge and use of astronomy. Write Susan Hall, Slana Via, Gakona, AK 99586.

WANTED — Any telescope larger than 4-1/4" reflector. Contact Tom Hanson, 307 Gainsborough Rd., Toronto, Ontario, CANADA M4L 3C8. Phone (416) 465-3984 (home), or 752-2530 (work).

WANTED — Books. "History of Telescopes" by H.C. King. "Atlas of Deep Sky Splendors" by Vehrenberg. "Observational Astronomy for Amateurs" by J.B. Sidgwick. Will pay good price. Contact James T. Paulsel, 306 S. Homewood, Pittsburgh, PA 15208. Phone (412) 241-3459.

WANTED — Mountaineering books and periodicals. State condition, price. Write Laurence F. Hawkins, 5976 Billings Rd., Parkdale, OR 97041.

WANTED — Correspondence with persons (preferably under 20) interested in science fiction, the space program, etc. Write Tony Hecht, 960 Ocean Ave., Sea Bright, NJ 07760.

WANTED — Regular correspondence with persons (preferably 14 or older) in southern California area interested in science fiction, astronomy. Write J.Y. Klukas, 5 Mareldor St., Hudson, MA 01749.

WANTED — Dome for elementary classroom projection (from Nova planetarium). Also Olcott's "Field Guide to the Stars"; must be in good condition. Write John LaMonte, 1210 Hill Dr., Los Angeles, CA 90041.

WANTED — ASTRONOMY back issues: September 1973 through February 1974; April through June 1974; August 1974 through April 1975; January 1976; February 1978. Write David Leef, 2709 Valecrest Rd., Crystal, MN 55422.

WANTED — Back issues of ASTRONOMY: September 1973 through February 1974, and May 1974. Must be in good condition. Send prices to Jim MacDougall, 43 Broad St., Williston Park, NY 11596. Phone (516) 746-0583.

WANTED — Permanent correspondence with astronomy oriented philatelists who would trade U.S. commemoratives, definitives (post 1963) for ASTRONOMY back issues (October 1976 through August 1978). Contact Aldon L. Miller, 2102 - 206 Fairmont Dr., Saskatoon, Saskatchewan, CANADA S7M 4P5. Phone (306) 382-2087.

WANTED — January 1974 issue of ASTRONOMY; American Ephemeris and Nautical Almanac (1959 and 1960); BAA Handbook (1971-73). State price. Contact Gary Peterson, 13348 23rd Ave. N.E., Seattle, WA 98125. Phone (206) 364-4848.

WANTED — ASTRONOMY back issues: September 1973 through February 1974; April 1974 through June 1974; August 1974 through April 1975; January 1976. Contact David Pollen, 36 Rutledge Rd., Belmont, MA 02178. Phone (617) 484-4840.

WANTED — A series (approximately 10 to 12) of 2x2 color slides of solar eclipse, Will consider copies of your favorites. Send details, prices to Andrew W. Poole, Box 30455, Charleston, SC 29407.

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WANTED — Persons interested in forming nonprofit organization dedicated to the encouragement of public education/research/government support pertinent to the search for extraterrestrial intelligence (SETI). Contact L. David Raub, 1125 Stanley Ave., Bethlehem, PA 18015. Phone (215) 867-1335.

WANTED — Suggestions, opinions, ideas on international space laws, regulations to be used as man ventures into space for interplanetary exploration, colonization and mining. Write Andrew Remus, 5488 N. Fruit, Fresno, CA 93711.

WANTED — Astronomers in the Phoenix, Ariz. area to join the Saguaro Astronomy Club, a new activity oriented association. Monthly meetings, star parties, observatory tours, much more. For information, call Pete at (602) 833-3724 or Gene (602) 934-1889.

WANTED — Brass Navy sextant in good condition. Write Scott Siglin, 1005 Prospect Blvd., Waterloo, IA 50701.

WANTED — ASTRONOMY back issues in excellent condition: October, November, December 1973; August 1974. State prices. Write Dan Spayde, P.O. Box 171, Mansfield, OH 44901.

WANTED — Correspondence with persons (around age 15) interested in "Star Trek". Write Mark Stalsberg, 129 Greenhill Dr., Viroqua, WI 54665.

WANTED — Correspondence with persons interested in astronomy, inventions, research, ufology, photography; to join research efforts of New Age World Scientific Foundation. Write Ramsay Vandertuin, c/o Science Dept., P.O. Box 3086, Huntington Park, CA 90255.

WANTED — January 1976 issue of ASTRONOMY. State condition and price. Write Iain C. Walker, P.O. Box 70, Greely, Ontario, CANADA K0A 1Z0.

WANTED — Meteorite rings set in silver, such as those formerly offered by House of Rings. Also information on whether House of Rings will re-open. Write Karen Wiles, 1543 Exchange St., #601, Astoria, OR 97103.

WANTED — "Bonner Durchmusterung"; back issues (1893-1951) of defunct "Popular Astronomy"; King's "History of the Telescope"; Richardson's "The Star Lovers"; Baade's "Evolution of Stars and Galaxies". Write Thomas W. Wilson, 216 Chestnut St., Huntington, WV 25705.

WANTED — Response from science fiction readers on their favorite novels or short stories (including authors). Write Debbie Larsen, 1260 W. Larpenteur, #210, St. Paul, MN 55113.

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WANTED — Correspondence with persons (ages 14 to 20) interested in astronomy, archeology, UFOs, paleontology, science fiction movie making. Write Steven Beckner, 5600 Scottwood Rd., Paradise, CA 95969.

WANTED — If you teach astronomy at the secondary school level, I'd like to swap classroom activities. Write Bill Byles, Earth-Space Science Instructor, Briarcrest Baptist High School, Box 17113, Memphis, TN 38138.

WANTED — Back issues of prominent scientific magazine established in 1845, employing Martin Gardner as regular monthly columnist: September 1960; January, February 1961; January, February 1965; March 1966. Trade or buy. Write Martin Davis Jr., 410 McClure Terrace, Chattanooga, TN 37415.

WANTED — 35mm SLR camera body. Contact Richard Wolf, Box 2127, Sunnyvale, CA 94087. Phone (415) 969-0609.

WANTED — January and February 1978 issues of ASTRONOMY; will pay $3.00 to $5.00 depending on condition. Also information and/or prices on astronomy project books. Write Jeff Phillips, 1016 W. Isleta Ave., Mesa, AZ 85202.

INFORMATION WANTED — On existing or proposed astronomy organizations/clubs in the New London/Groton/Norwich area. Also information on starting an astronomy club. Write Joan Mackiewicz, 19 Riverview Rd., Uncasville, CT 06382.

INFORMATION WANTED — On star parties. Also plans for construction of an observatory, and cold camera plans for 8" Newtonian. Write David Bearden, Rural Route, Fargo, OK 73840.

INFORMATION WANTED — On any amateur astronomy club in eastern or central North Carolina. Have 12-1/2" reflector. Contact Virgil H. Day, Rt. 1, Box 375, Beaufort, NC 28516. Phone (919) 728-3038.

INFORMATION WANTED — On areas of geomagnetic anomaly where light and gravity apparently go amuck. Contact Allan Grise, 2810 Pearl St., Santa Monica, CA 90405. Phone (213) 450-2057.

INFORMATION WANTED — On systems or ideas for observing astronomical objects from inside a building. Contact Thomas Little, 487 West Rd., New Canaan, CT 06840. Phone (212) 966-2160.

INFORMATION WANTED — On any astronomy club in Merced area. Also information on any state clubs in California. Write Rob Luzitano, 739 San Diego Ct., Merced, CA 95340.

INFORMATION WANTED — Reports of UFO sightings in Midwest, and any other information on ufology. All correspondence welcome. Write Kathy Okon, 4585 Westfield Ct., Bay City, MI 48706.

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INFORMATION WANTED — On any astronomy clubs in Macomb County, Mich. Contact Bruce Popovich, 24460 Antoinette, Warren, MI 48089. Phone (313) 757-2392.

INFORMATION WANTED — On astronomy club or persons interested in forming same in Joliet, Ill. area. Write Mike Priesbe, 314 Arrowhead Dr., Shorewood, IL 60435.

INFORMATION WANTED — Books, tapes, magazine articles on black holes, miniblack holes, white holes. Write Al Rauch, 3837 Chalfont Dr., Philadelphia, PA 19154.

INFORMATION WANTED — On how to get into a career with NASA as an exobiologist, astronomer, astrophysicist, etc. Write James Schuler, 527 E. Polk St., Richardson, TX 75081.

INFORMATION WANTED — On nearby stars out to 40-50 light-years (size, age, companions, spectral type, coordinates, possible planets, etc.). On brown dwarfs, black holes. On amateur astronomers, clubs in Salem area. Write Jon Ziegler, 1517 Shady Ln., Salem, OH 44460.

INFORMATION WANTED — On any amateur astronomy club in the Lancaster area. Write John Stewart, 232 N. Shippen St., Lancaster, PA 17602.

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ANNOUNCEMENT — The Springfield Amateur Astronomers Association is accepting new members of high school age. If interested, contact Jim Newman, 8227 Taunton Pl., Springfield, VA 22152; phone (703) 569-2518. Or Christian South, 8505 Fairburn Dr., Springfield, VA 22152; phone (703) 569-0509.

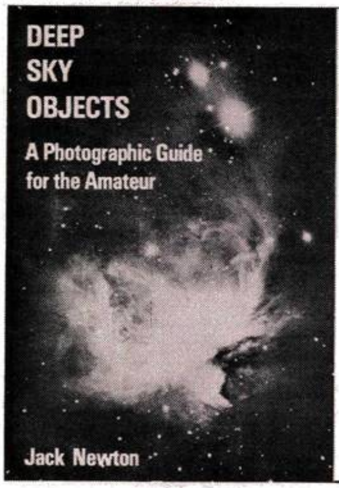
ANNOUNCEMENT — Poor, scrounging researcher has new method that can produce a high resolution color map of Pluto. Need large (30"+) telescope time and funding for success. For information, contact Bruce A. White, 5707 Westward-#56, Houston, TX 77081. Phone (713) 776-3057.

ANNOUNCEMENT — Correlation Center for UFO Studies retains Canadian, U.S. reports in central file. Send your UFO reports; all correspondence confidential. Write CCUFOS, P.O. Box 174, St. James Post Office, Winnipeg, Manitoba, CANADA R3J 3R4.

ANNOUNCEMENT — Persons interested in joining a "Star Trek" club, Starfleet, please contact Peter Charette, Portland Rd., Marlborough, CT 06447. Phone (203) 295-9417.

ANNOUNCEMENT — "Future Wings", a charming new "Star Trek" fanzine with a light-hearted touch and a dash of the old RCAF. For details, send SASE (Canadian letter postage now 14¢) to Jeanette Eilke, CFB Chatham, Curtis Park, New Brunswick, CANADA E0C 2E0.

ANNOUNCEMENT — The Birmingham Astronomical Society meets the 4th Tuesday night of each month. All persons interested in astronomy are welcome. For information, contact Jim McDowell, 105 Meadow Trail, Warrior, AL 35180. Phone (205) 647-2583 or 326-8236.



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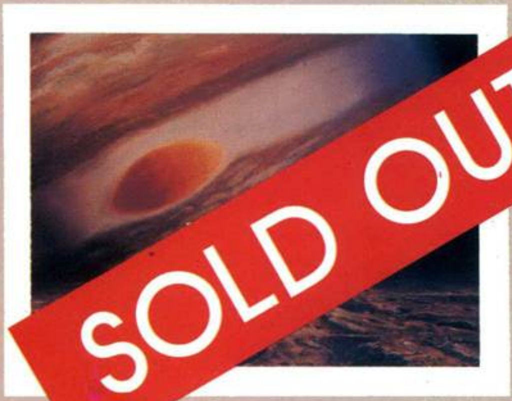

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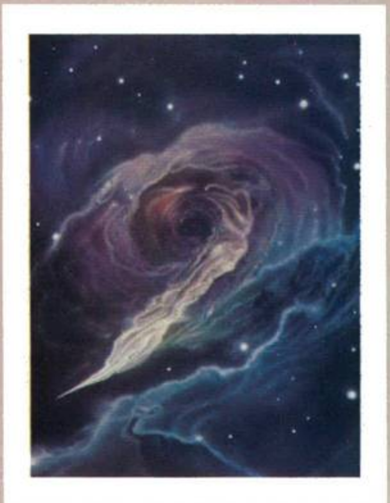
Jupiter From Io

[illegible] dramatic painting [illegible] an incredible [illegible] man may [illegible]ness first [illegible] incredible [illegible]piter looming [illegible] the surface of its [illegible]atellite Io. Located deep within Jupiter's intense magnetic field, Io is one of the most lethal places in the entire solar system. To view this scene, we must rely on the imagination of artist John Clark.



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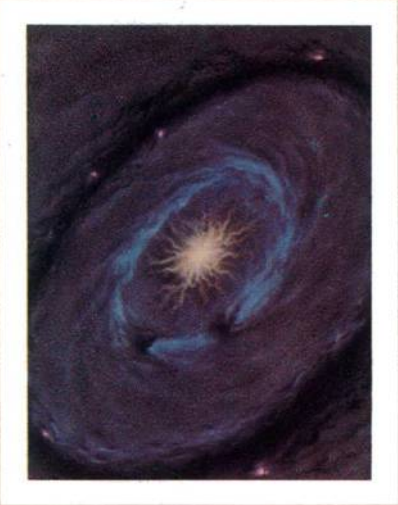
Black Hole

A nearly invisible small black hole speeds through a dense interstellar cloud of gas and dust, leaving behind a trail of gravitationally disturbed material. The infalling material becomes hot and emits light as it drains out of the known universe. Artist Mark Paternostro speculates on the appearance of these still undetected objects.



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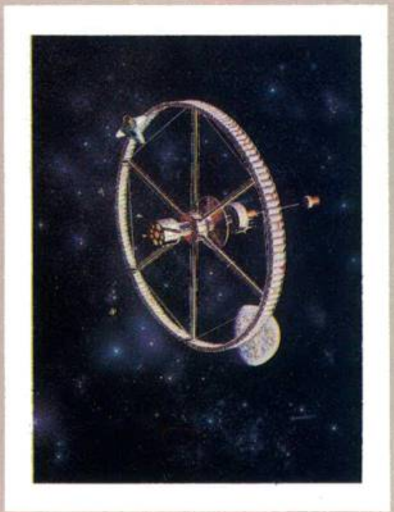
The Galactic Core

The nucleus of our galaxy is one of the true unknowns in our universe. Recent radio and infrared observations suggest that two titanic swirling rings of gas and dust occupy the core of our galaxy. These rings were apparently produced by an explosion 10 million years ago. Victor Costanzo's painting indicates that actual conditions at the galaxy's center remain a mystery.



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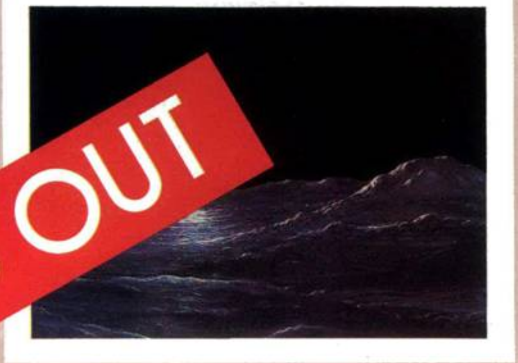
What will space stations and orbiting colonies of the future look like? Artist Rick Sternbach provides an ingenious answer in his painting of a mile wide space station wheeling slowly above the gibbous Earth. Shuttle rockets near the station's hub bring ore from the lunar surface for refinement in the station's zero gravity manufacturing center.



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Plut[illegible]

The setting sun glints off a low plain of [illegible] ice on the surface of the smalle[illegible] distant planet, Pluto. The co[illegible] scene — completely alien [illegible] comes to life in this [illegible] The mysteries of [illegible] as we stand [illegible]bly distant s[illegible]

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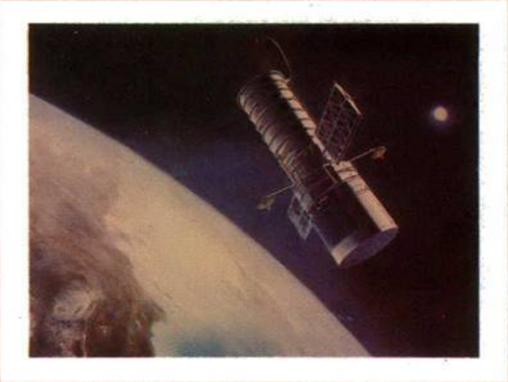

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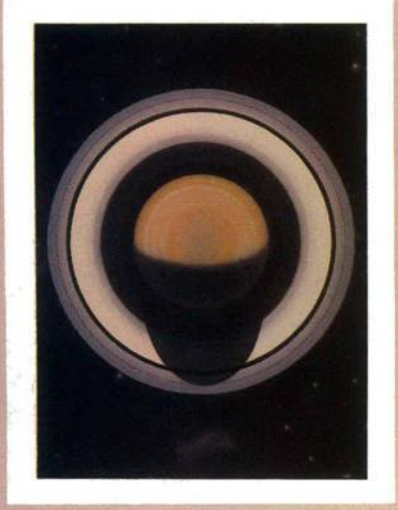
Space Telescope

Painted by John Clark from official NASA blueprints, this poster depicts the Space Telescope — a powerful 94 inch (2.4 meter) aperture telescope due to be launched during the early 1980s by NASA's Space Shuttle. This is an accurate depiction of an instrument that will revolutionize man's view of the universe during the decades it remains in operation.



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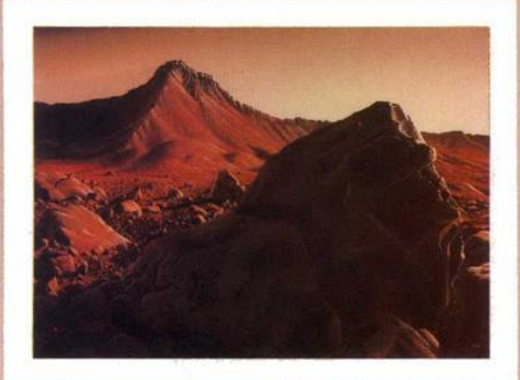
Saturn

In an unusual perspective from above the north pole of Saturn, we can identify the planet's three main rings and their sizes relative to Saturn itself, enabling us to grasp the vast extent of Saturn's ring system. This remarkable painting by Adolf Schaller gives us a view of the planet not obtainable from Earth.

Vallis Marineris

Photographs returned from Mariner and Viking probes revealed for the first time the immensity of Vallis Marineris, the equatorial canyon of Mars. This painting by Adolf Schaller — meticulously transcribed from overhead Viking photos — takes us to the foot of a blanket of landslide rubble in the canyon itself.



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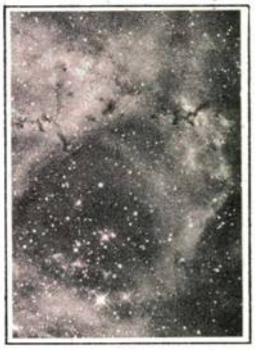

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STAR DOME

AUGUST

by

John G. Harmon and James Mullaney

As mentioned last month, the brighter stars of Sagittarius form a "teapot" shaped asterism, which actually comprises only a small part of the whole constellation. Sagittarius includes a region of stars to the east of the teapot which is even larger than the teapot itself.

This entire group is almost universally known as an archer, complete with bow and arrow. However, the exact nature of the archer himself varies from culture to culture. Greeks and Romans saw him as a Centaur — half-man, half-horse. The Egyptians' version gave him a lion's face in addition to a human one. The early Sumerians identified him with Nergal, their archer god of war. This seems, in fact, to be the origin of the constellation, and the image of the archer was important enough to be sculpted on some of their boundary stones.

There are some exceptions to this view. The Chinese saw Sagittarius as a tiger, and included it in a much larger group, "the azure dragon", which stretches along the zodiac all the way back to Virgo. Later, after the coming of the Jesuits, Sagittarius changed to Jin Ma, or the man-horse. The people in India saw a horse or horse's head, although they sometimes pictured the teapot portion as a fan of lions' tails. Early Arabians selected some of these stars for a separate asterism. Parts of the arrow of Sagittarius were seen as ostriches — some heading for, and others returning from, a drink at the celestial river of the Milky Way.

The brightest star in Sagittarius does not bear the Greek letter alpha as you might expect. Alpha instead belongs to a star which is actually two magnitudes fainter. Its Arabic name is Rukbat, from Rukbat al Rami, or the archer's knee. Beta is actually two stars side by side. Known collectively as Arkab, they designate "the tendon uniting the calf of the leg to the heel". (The Arabs were often anatomically precise when describing a constellation.) Sagittarius' armpit is Ascella, or Zeta, and a pair of stars listed as Nu are called Ain al Rami (the archer's eye). Other parts include Gamma, which is Al Nasl, the tip of the arrow, and Delta, Epsilon and Lambda, which are all parts of the bow.

Deviating from this scheme is the star Sigma Sagittarii, or Nunki. One of the brightest in the constellation, it is "the star of the proclamation of the sea". The "sea" was an ancient designation for the part of the sky which follows Sagittarius from Capricornus to Pisces. Lastly we come to Omega, which was named in Latin rather than Arabic. It is Terebellum, and it marks the hindquarters of the centaur-archer.

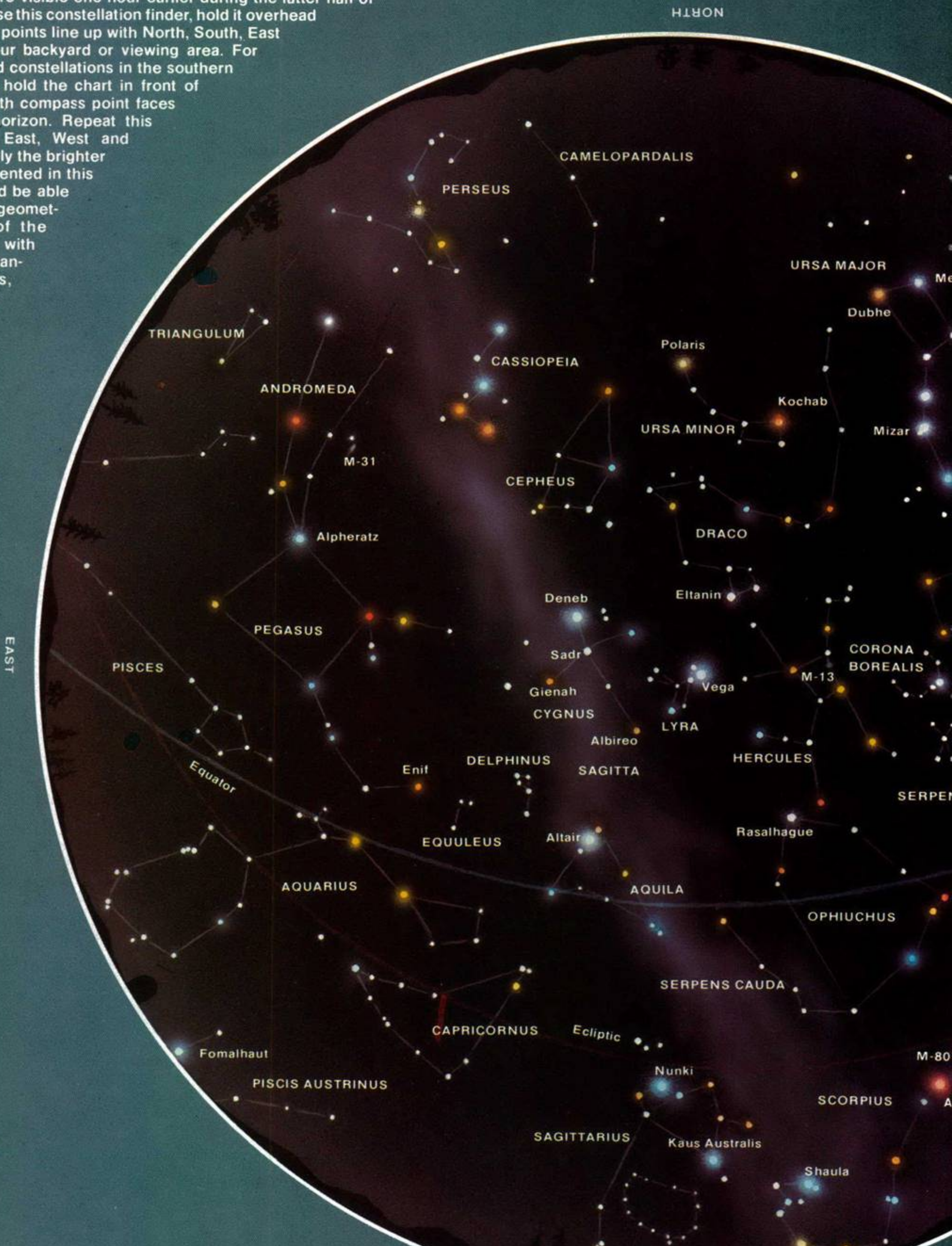
In this region near the center of our galaxy are a number of other small constellations. Almost surrounded by the stars of Sagittarius is Corona Australis, the southern crown. This curved line of stars is not very prominent, but its recognition as a constellation is apparently quite ancient — dating back to the time of Ptolemy. It was thought by some to be a centaur's crown and was also known as Corona Sagittarii. Others thought it might be the crown placed in the sky by Bacchus to honor his mother. Also known as Dionysius, he was the son of Semele and the god Zeus.

Another early concept saw Corona Australis as a bunch of arrows in the hand of the archer, a picture which fits with its proximity to Sagittarius. The Arabs also saw this group in a number of ways. It was the "ostriches' nest" or the "woman's tent" because of its shape. Even earlier, it was seen as the tortoise by both the Arabians and Chinese.

Above Sagittarius along the Milky Way is another minor group, Scutum Sobieski. This is a more "modern" constellation invented by the Polish astronomer Hevelius, who also gave us Lynx. The constellation represents the shield of Sobieski (the king of Poland at the time Hevelius published his star catalog in 1690).

Even smaller is Telescopium, a group of dim stars between Corona Australis and Scorpio. It is also a newer constellation, having been

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page


NORTH
CAMELOPARDALIS
PERSEUS
URSA MAJOR
Me
Dubhe
TRIANGULUM
Polaris
CASSIOPEIA
ANDROMEDA
Kochab
URSA MINOR
Mizar
M-31
CEPHEUS
DRACO
Alpheratz
Eltanin
Deneb
PEGASUS
CORONA BOREALIS
Sadr
PISCES
M-13
Vega
Gienah
CYGNUS
EAST
LYRA
Albireo
HERCULES
Enif
DELPHINUS
SAGITTA
Equator
SERPEN
Rasalhague
EQUULEUS
Altair
AQUARIUS
AQUILA
OPHIUCHUS
SERPENS CAUDA
CAPRICORNUS
Ecliptic
M-80
Fomalhaut
Nunki
PISCIS AUSTRINUS
SCORPIUS
A
SAGITTARIUS
Kaus Australis
Shaula
CORONA AUSTRALIS
SOUTH

Map Centered on 43° North Latitude

rak
CANES VENATICI
Cor Caroli
COMA BERENICES
BOOTES
Arcturus
lphecca
S CAPUT
VIRGO
LIBRA
ntares
WEST

Map by Adolf Schaller

introduced by La Caille in the mid-18th century.

All the groups, both great and small, mentioned in this and last month's Star Dome, are situated on or near the Milky Way. This hazy band is composed of gas, dust, and millions of distant stars in the plane of our galaxy. While individual stars cannot be seen with the unaided eye, their light blends to form a diffuse glow. We can't even see all the stars in our galaxy because of interstellar dust, which gives rise to dark lanes or rifts. In the direction of Sagittarius, the dust permits us to see only about 1/10 the way to the center of our galaxy. But if we look away from the plane of the Milky Way, our view can extend billions of light-years out into the universe.

The name "Milky Way" is derived from the story of Hercules and Hera, the wife of Zeus. Hercules was the son of Zeus by the mortal, Alcmena. In order for children of Zeus to enter heaven, however, they first had to be suckled by Hera. The infant Hercules was brought to Hera by Hermes (Mercury). At the last moment, she recognized him as not being one of her own children and shook him off. Her milk was splashed across the sky and formed the Milky Way. This seems to be the most common explanation for this hazy band.

There are different views, however, which compete in other parts of the world. Some people saw it as the River of Heaven, River of Light, or the Celestial River. Another common view was that it was a pathway of souls on their way to Valhalla or other realms of the hereafter. The Ethiopeans and Chinese saw it as a road of chopped straw.

But of all of these, perhaps the most fanciful picture of the Milky Way comes from Polynesia, where it is seen as a long, blue, cloud eating shark.

The true nature of the Milky Way was not fully known until this century. The process of discovery began in 1610 when Galileo published **The Sidereal Messenger** and announced the wonders revealed to him by his telescope. In addition to the moons of Jupiter and mountains on the moon, Galileo saw that the Milky Way was composed of stars.

Early models of the galaxy had it lens or "grindstone" shaped with our solar system at the center. The advent of radio astronomy enabled astronomers to penetrate the interstellar dust, and the spiral shape of the Milky Way and our position in it were finally known. We no longer place ourselves at the center, but rather about 2/3 of the way out from it, in or near one of the spiral arms, with our sun only 1 of about 100 billion stars orbiting the nucleus!

Close-Up

Sagittarius Region (Part 2)

We continue our extended two-part survey of the magnificent Sagittarius region, this time focusing our attention on the wonders south and east of the dense Milky Way stratum. Included are a few specimens from neighboring Corona Australis, a tiny constellation situated just below the well-known teapot. There's a definite scarcity of descriptive comment by the classic observers, perhaps because of the rather low elevation of many of the objects above the southern horizon. Olcott, for example, apparently bypassed this month's offerings entirely, while Barns — despite his site in California — limited his sky coverage to -20 degrees declination. That's all the more reason for you to explore these regions with us — regions where few have left their mark!

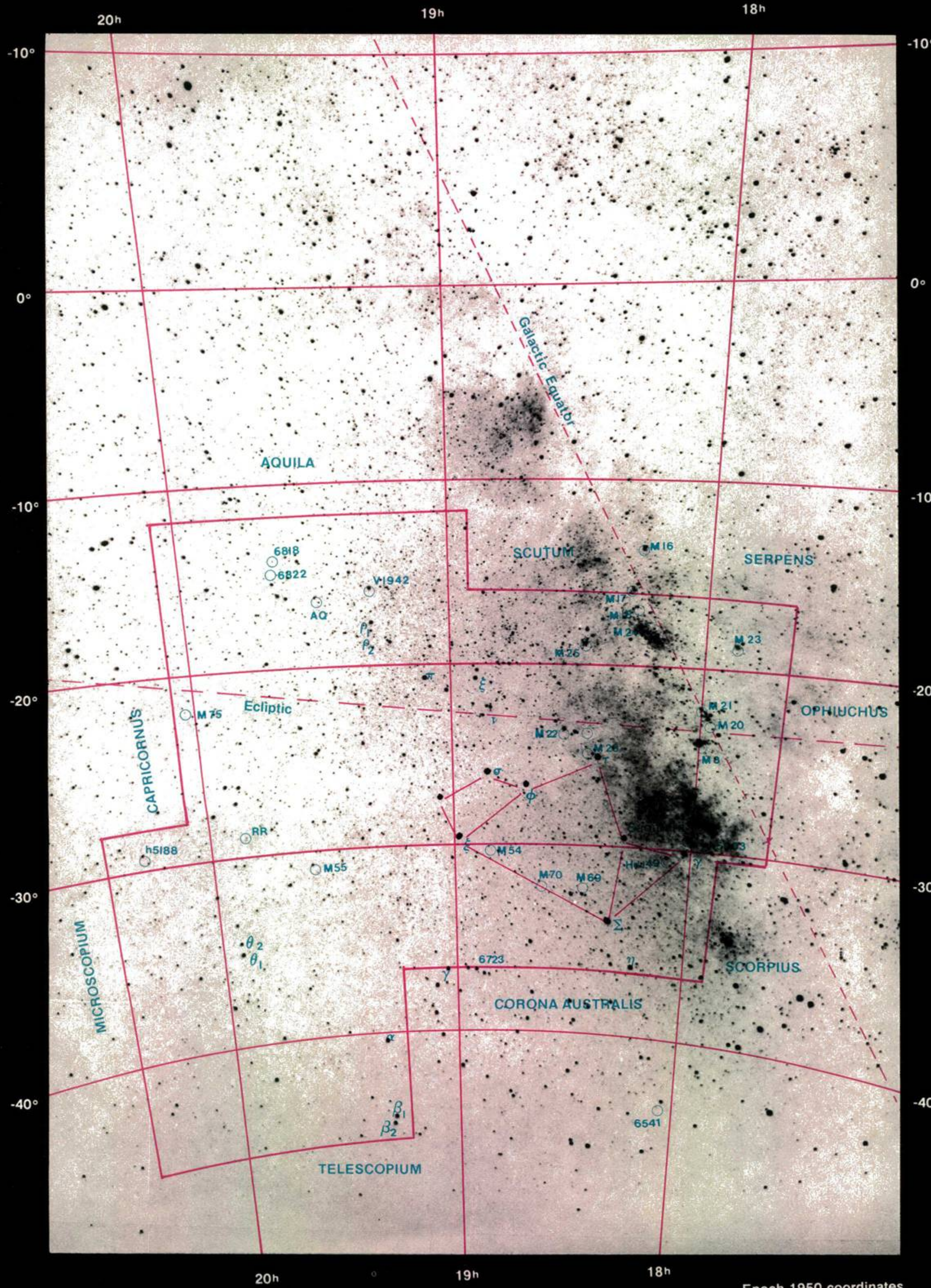
NGC-6818

We'll begin with the most northerly objects, and work our way southward. Our first selection is the very blue planetary nebula NGC-6818, also designated H-IV^{51} — the 51st discovery in Sir William Herschel's class IV (planetary nebulae). Sweep for it with medium power on your telescope about two degrees north and slightly east of the naked eye stars 54 and 55 Sagitarii.

This cosmic egg measures 22 by 15 seconds of arc in apparent size and glows near 10th magnitude. Although classified as annular or ringlike in form, it appears as a uniform oval even in large sized homemade instruments. In common with most planetaries, NGC-6818 looks nearly starlike in three and four inch telescopes at low power, but reveals a small disk at medium to high magnification. In eight inch or bigger scopes it is a stunning sight, as our drawing with a 13 inch Fitz-Clark refractor at 365 power indicates.

This object appears on the roster of the 35 finest planetaries compiled by Tom Reiland (see ASTRONOMY, August 1977), where it is given the appropriate name "Little Gem". Webb described it as "Planetary, blue, like star out of focus. Earl of Rosse and d'Arrest darker center; John Herschel otherwise." The NGC records it as "Bright, very small and round."

NGC-6818's outstanding feature is its eerie color. The late John Mallas considered it one of the bluest planetaries in the sky, and few have seen as many as he did in his exhaustive visual survey of the heavens with a four inch refractor. Bernhard, Bennett and Rice gave its


20h
19h
18h
-10°
0°
-10°
-20°
-30°
-40°
Galactic Equator
AQUILA
SCUTUM
SERPENS
OPHIUCHUS
CAPRICORNUS
MICROSCOPIUM
TELESCOPIUM
CORONA AUSTRALIS
SCORPIUS
Ecliptic
6818
6822
V1942
AQ
ρ1
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M16
M17
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M24
M25
M23
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M54
M75
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M55
M70
M69
γ
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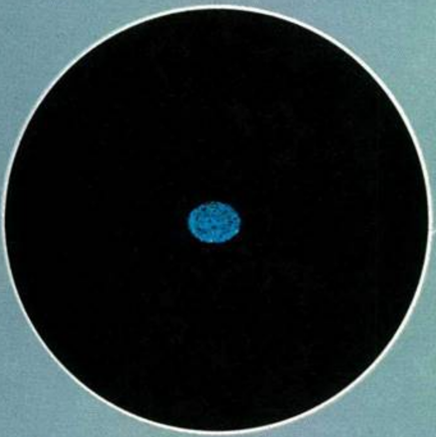
θ1
6723
η
α
β1
β2
6541

Photograph by Brad Wallis and Robert Provin / Map by Richard Berry

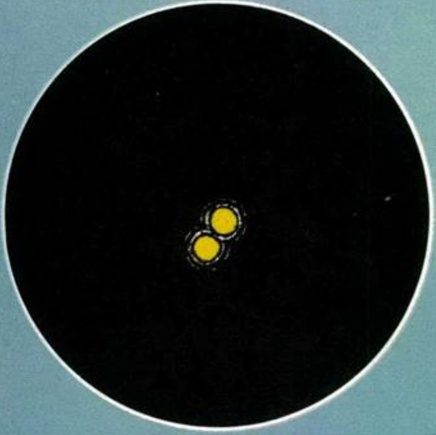
Epoch 1950 coordinates

NGC-6818



365x 13″ Fitz-Clarke refractor

Gamma Coronae Australis



180x 3″ refractor

tint as pale blue, while Barns found it looking "like a monster fish eye" in his 10 inch reflector!

NGC-6822

Less than one degree south and slightly east of NGC-6818 lies NGC-6822, better known as Barnard's galaxy (named after its discoverer). Although reportedly visible in a finder on a dark transparent night, it's best picked up by sweeping with a low power, wide angle eyepiece on the telescope itself.

This elongated cloud measures at least 16 by 11 minutes in extent and glows softly near ninth magnitude. Although some authorities rate it as faint as 11th, it appears on most lists of the brightest galaxies. A dwarf irregular system, NGC-6822 is a member of the Local Group of galaxies (which includes the Andromeda spiral and the Milky Way itself). NGC-6822 lies relatively close to us — "only" 1,700,000 light-years away! This accounts for its unusual visibility so near the "zone of avoidance" created by absorption in our own galaxy, which contributes a fairly rich curtain of stars to the field.

Top: NGC-6818 resembles a glowing blue celestial egg in a large telescope at high power, but with small telescopes it appears almost starlike. Its disk is oval and slightly less than half the telescopic size of Jupiter. Bottom: Gamma Coronae Australis is a close pair of nearly identical yellowish stars. You'll need good seeing to separate this "dynamic duo" because of its low southern declination. Drawings by James Mullaney.

Selected Objects — Sagittarius Region (Part 2)

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.
†NGC-6541	GC	6	6′	18^h04^m	-43°44′
*M-69	GC	7.7	3′	18^h28^m	-32°23′
*M-70	GC	8.2	2′	18^h40^m	-32°21′
*M-54	GC	7.7	2′	18^h52^m	-30°32′
NGC-6723	GC	7	6′	18^h56^m	-36°42′
*Gamma CrA	★2	5.0,5.1	1.6″	19^h03^m	-37°08′
V1942	IV	6.7-7.1	—	19^h16^m	-16°00′
Beta-1	★2	4.2,7.3	18″	19^h19^m	-44°33′
AQ	SRV	6.6-7.6	200^d	19^h31^m	-16°30′
*M-55	GC	6.1	10′	19^h37^m	-31°03′
*NGC-6818	PN	10	22″x15″	19^h41^m	-14°17′
*NGC-6822	IG	9	16′x11′	19^h42^m	-14°53′
RR	MV	5.6-14.0	334^d	19^h53^m	-29°19′
*M-75	GC	8.3	2′	20^h03^m	-22°04′
h-5188	★3	6.3,8.3,8.0	4″,27″	20^h17^m	-29°21′

*Detailed in Close-Up

†In Corona Australis

GC = Globular Cluster
★2 = Double Star
★3 = Triple Star
IV = Red Irregular Variable
SRV = Red Semiregular Variable
PN = Planetary Nebula
IG = Irregular Galaxy
MV = Red Long Period Variable
Mag. = Magnitude
Sep. = Separation
Per. = Period

Barnard's galaxy was unknown to the Herschels, Webb and most of the other classic observers, having been discovered in comparatively recent times. Knowing just what to look for is more important than telescopic size: The great astronomer Edwin Hubble found it "fairly conspicuous" in a four inch scope but nearly invisible in the 100 inch reflector at Mt. Wilson! It filled the entire field of the latter instrument, resulting in poor contrast with the sky around it.

The NGC calls this galaxy "Very faint, large, extended, diffused." A four inch RFT at 15 power will show it on a good night, and the view in a six or eight inch reflector at 50 diameters or so is perhaps optimum. Look for a misty patch of light elongated in a north-south direction in the sky.

M-75

Next is the northernmost of the swarm of globular clusters scattered through this month's region: M-75. It lies in a rather blank area of the sky near the Capricornus border, but can be found by carefully sweeping with a low power eyepiece one hour (15 degrees) due east of Omicron (*o*) Sagittarii, or about five degrees north and one degree east of 62 Sagittarii.

This eighth magnitude bundle of stars is just two minutes in diameter and is considered one of the most highly concentrated members of its class. Strangely, Bernhard, Bennett and Rice called it "a globular with a bright nucleus, and the most 'open' of the large globulars". The words "open" and "large" in this account suggest they may have been intended for the globular M-55 (see below).

M-75 is small, faint and highly condensed as globulars go. In fact, most observers find it disappointing on first inspection. It can be seen in finders and binoculars but appears as only a hazy spot in three and four inch telescopes — even at high powers. A night offering *both* good seeing (image steadiness) and transparency is necessary to begin picking up individual stars in medium sized instruments. An 8 or 10 inch aperture at 150 power or more begins to resolve this object's outer edges under good conditions.

Webb saw M-75 as just a "bright nucleus with low power" in his 3.7 inch refractor, while Holyoke found it "small but bright and easy...not resolved by a six inch telescope". The NGC impression is "Bright, pretty large, round, very much brighter in the middle, bright nucleus, partially resolved, some stars seen." It makes a good "warmup" object enabling us to better appreciate the true glory of showpieces like our next offering.

M-55

Should you find M-75 a letdown,

proceed immediately to M-55 — a magnificent globular guaranteed to rekindle your enthusiasm! It's readily swept up on a dark night with a finder or low power eyepiece some eight degrees east and one degree south of the star Zeta (ζ) Sagittarii. As Holyoke remarked, it is "far from any good guide stars and only its brightness makes it easy to find".

Shining near sixth magnitude and measuring at least 10 minutes of arc in diameter (some sources make it fully twice this size), M-55 is among the largest and brightest globulars in the sky. Many visual observers feel it resembles the famed M-13,and were it farther north, it would surely rival the great Hercules cluster. As it is, this stellar beehive lies far enough south that a first class night is needed to fully appreciate its splendor.

M-55 is at the opposite end of the concentration scale from M-75. Its loosely packed stars make it easy to resolve when air is steady. Though it looks like a fuzzy ball in three and four inch telescopes at 45 power, it begins to break up into stars at 90 power or more on a typical night. A six inch at 100 power shows stars right into its glittering core, while the view in eight inch and larger instruments is simply overwhelming!

Muirden called it "a large, bright globular cluster, with little central condensation", and the NGC said: "Pretty bright, large, round, very rich, very gradually brighter in the middle, stars from 12th to 15th magnitudes." M-55 certainly deserves much more acclaim than these few rather lukewarm accounts give it — as you'll discover for yourself when you see it! We view this glorious orb from across nearly 20,000 light-years of interstellar space, richly set against the starry fringe of the summer Milky Way.

M-54

Between the stars Zeta (ζ) and Epsilon (ϵ) in the bottom of the teapot lie three additional Messier globulars in a neat row, spaced several degrees apart. The first of these is M-54, a small bright bundle of stars easily picked up in a finder just 1-1/2 degrees southwest of Zeta.

At magnitude 7.7 and two minutes of arc in diameter, this cluster is much fainter and smaller than M-55 — it somewhat resembles M-75, but is brighter and easier to resolve into stars than that object. Holyoke remarked that although M-54 and its two neighbors, M-69 and M-70 (see below), were all easy to find in a small telescope, only low powers could be used effectively because of their low altitude. He was unable to resolve any of these globulars with his six inch reflector.

Muirden called M-54 "An unusual globular cluster; center so condensed that it looks like an eighth magnitude star with a hazy surround." Kenneth Glyn Jones —the noted British observer and Messier authority — found this object looking almost like a planetary nebula upon first inspection. The NGC described it: "Very bright, large, round, gradually, then suddenly much brighter in the middle, well resolved, clearly consisting of stars, 15th magnitude and downward." Can you add anything to these brief accounts with your own eyes and telescope?

M-69 and M-70

The other globulars in this cosmic lineup look similar to M-54 as well as to each other. They are M-70 (located three degrees southwest of M-54 and midway between Zeta and Epsilon), and M-69 —situated two degrees due west of M-70 and roughly an equal distance northeast of Epsilon. They can be seen together in a finder, and all three clusters lie in the same field through 10x50mm wide angle binoculars!

M-70 glows at 8.2 magnitude and measures two minutes in diameter, M-69 is brighter at 7.7 magnitude and slightly larger at three minutes across Both objects are considered of medium concentration as globulars go. The NGC description for M-70 is "bright, pretty large, round, gradually brighter in the middle, stars from 14th to 17th magnitudes"., and for M-69: "Bright, large, round, well resolved, clearly consisting of stars, from 14th to 16th magnitudes."

Despite Holyoke's inability to resolve them, all three globulars show mottling —the precursor of actual resolution — in four to six inch scopes at medium power when seeing is good. With averted vision, individual stars can be glimpsed around their edges in larger instruments. Here, again, published descriptions of these objects are sparse, so why not have a look the next clear night and record your visual impressions to share with others? For best results, these small tightly packed spheres should be observed when directly on the meridian, at their highest in the sky.

Gamma (γ) Coronae Australis

We conclude our survey of this month's region with a low-lying but attractive double star for small telescopes — readily picked out with the unaided eye on a dark night despite its declination of -37 degrees. The star is Gamma Coronae Australis, topmost of the gems marking the southern crown and situated just one degree northwest of Alpha (α).

Here we find two nearly matched fifth magnitude suns, currently 1.6 seconds apart near position angle 165 degrees. Both stars are of spectral class F7 and appear — with a little help from atmospheric absorption at these low altitudes — yellowish in tint. They are a superb sight in a three inch refractor at 180 power as shown in our drawing, which reveals the spurious diffraction disks and rings that appear in good seeing with small apertures.

Gamma is a physical binary system, one of the thousands of pairs found by Sir John Herschel during his famed survey of the southern sky from South Africa. As such, it also carries the designation h-5084 in his double star catalog. Its exact orbital period has been calculated as 120 years. Since the discovery, stars have completed more than one full circuit!

This duo was widest most recently in 1940 at a separation of about 2.7 seconds, and it's now closing to a minimum of 1.3 seconds (expected in 1992). In 1973, the two suns were in a north-south line (position angle 180 degrees), but are already noticeably changed from that direction due to orbital motion. By the time of closest approach 14 years from now, the position angle will have decreased to near 90 degrees, and the stars will be aligned in an east-west direction!

Determining the position angles of pairs like Gamma, where the components are so perfectly matched (less than 1/10 magnitude in this case), presents a problem for the visual observer. This important angle is reckoned from the primary or brighter member of a pair —but which star do we so designate when they are nearly identical? Such confusion can cause two equally reliable sources to give conflicting figures. One source cited the position angle of Gamma (in 1943) as near 55 degrees, while the other made it 225 degrees — nearly 180 degrees or a half orbit different!

Leaving such technicalities behind, why not have a look at this lovely pair of orbiting suns with your scope the next clear, tranquil evening? Having once seen this "dynamic duo", you'll very likely want to follow them over the coming years as they move about each other in the depths of space.

We cannot take leave of Sagittarius without remembering that when we look at this thrilling region, we are gazing in the direction of the central hub of our vast Milky Way star system. It is from this center that an expanding wave of creation moved out across the galaxy, spawning new suns and planets — and ultimately, perhaps life itself — in its path. Here we are looking back in space and time to the source of those forces that long ago lit up our spiral arm. Might we, while looking, wonder with writer James Hoey: "Could it be that, at times, while looking at the night sky, it's possible to feel an ever-so-slight nagging of our genetic makeup, like something almost but not quite remembered?"

The Celestron Telescope

Celestron 750mm Mirror Lens shot

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